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DRYCLEANING
OF
COTTON FABRIC

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

This report was prepared under contract for the United States Department of Agriculture by the Institute of Textile Technology, Charlottesville, Virginia. It was condensed for Agricultural Research Service by E. Fred Schultz, Jr., Biometrical Services and B. M. Kopacz, Southern Utilization Research and Development Division, New Orleans, Louisiana.

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[1] Present address: 571 Crestwood Drive, Cookerville, Tennessee.

ABSTRACT

A laboratory drycleaning unit was developed similar in operation to commercial units. Test swatches (6 in. x 6 in.) of a single 80 x 80 cotton printcloth were soiled uniformly with the single nongreasy, water insoluble soil, lamp black. These were drycleaned together with similar but unsoiled swatches to determine the amount of soil removed from soiled swatches and redeposited on clean swatches.

Degree of soiling was measured as percent light reflectance. The theory of soil measuring is discussed and percent soil removal as estimated from fabric reflectance values was computed and compared with similar values from the same fabrics prepared as chopped fiber pads to eliminate orthogonal nonuniformity of soiling. For comparisons in the interesting range of soil removal, and especially for comparisons within a single detergency system, it is suggested that the comparison of percent soil removal values calculated with the Bacon and Smith equation from the K/S values as computed by the Kubelka-Munk relation from fabric reflectance percentages is a valid procedure.

Comparison of Stoddard solvent and perchloroethylene showed that perchloroethylene may be used in place of Stoddard solvent with proper selection of additive, though there is a tendency for soil redeposition to be higher with perchloroethylene than with Stoddard solvent, with some additives. Fifteen other organic solvents were evaluated as drycleaning solvents for cotton fabric. Some had better detergent properties when used alone than did the standard drycleaning solvents, Stoddard solvent and perchloroethylene. However, none were as good as were the standards when used with the proper additive and water concentration with the exception of 10 percent of dichloroethyl ether in perchloroethylene which gave results as good as, or better than perchloroethylene alone.

Investigations into laundry drycleaning practice showed that drycleaning efficiency of Stoddard solvent was improved by adding certain surfactant reagents, notably Alrolene 70, Acto 450, Acto 700, and glyceryl monooleate. The effectiveness of the surfactants was increased by adding water to the system, but care must be exercised in making the addition and in controlling the amount. Temperatures in the range of general plant practice, 10° to 40° C., were the most satisfactory. Soil is removed more rapidly in the first stage of dry-cleaning than in the latter stages. The total soil removed is increased by longer washing time, longer filtering, and more rapid solvent filtering rate. The water soluble soils, sugar and salt, were found to transfer from contaminated to uncontaminated cotton fabric during drycleaning with Stoddard solvent.

The results are reported in four parts:

I. The Development of a Laboratory Drycleaning Unit Similar in Operation to Commercial Units.

II. Use of Reflectance Measurements in Determining Amounts and Efficiencies of Soil Removal.

III. Evaluation of Drycleaning Materials and Practices for Cotton Fabric Soiled with Nongreasy Water-Insoluble Soil.

IV. Preliminary Investigations in the Drycleaning of Cotton Fabric Soiled with Water-Soluble Soil.

GENERAL INTRODUCTION

A large number of variables are operating in even the simplest detergent system. Many of these variables are known, but evidently there are still those that have not been discovered. Under service conditions the interaction of these variables is probably nonlinear and highly complex. This does not mean that the evaluation of detergent efficiency in the laboratory is a completely hopeless task; but it does mean that such evaluation requires a wide and fundamental knowledge of the field, and that the greatest caution must be taken in planning experiments and interpreting the results obtained.

The decision to restrict the scope of this study by controlling the variables of temperature, bath load and agitation, and by using only a single lot of fabric with only a single type of soil was taken advisedly in an effort to insure positive findings. The thought behind this was that the data accumulated from the study would be sufficient to yield some positive information about a limited area of drycleaning practice, but probably would be totally inadequate if the whole field of variables were included. In view of the decision to restrict scope, and in anticipation of questions about the applicability of the findings of this study to practical drycleaning, the following factors are discussed in their relationships to general drycleaning practice and to this study.

The nature of the fiber or fiber mixture.—In the present study, which is confined to cotton, this factor is reduced to the variability of the cotton fiber of commerce. The laboratory tests were made on a single large batch of cotton fabric procured from one source, and presumably woven from a highly uniform blend. This means, possibly, that the experimental results may be shown some day to apply to this one type of fabric only. However, it enables asessment of the treatment effects of these experiments without interference of the possible differences from lot to lot of fabric.

The effect of yarn and fabric structure.—In this case also the use of a single batch of fabric reduces this variable to a minimum in laboratory tests. In service tests this variable could be of major importance.

The variability of the soils used for testing or found in service.—In the laboratory tests a single non-greasy soil prepared by a standard procedure has been applied to the test fabric under controlled conditions. While this is necessary to obtain valid results, it is one of the major reasons for uncertainty in correlating laboratory tests with service performance.

The effect of variations in temperature, bath load, severity of agitation, or concentration of detergents and moisture in the detergent process.—The concentration of detergent is one of the working variables included in this study. Laboratory tests are made under conditions of controlled temperature, bath load, and agitation. This is not the case in commercial drycleaning plants and is one of the reasons why service evaluations do not agree better with laboratory tests.

The distribution of the soil in the fabric.—This variable is given extensive consideration in this work. It is possible, by chopping the test fabrics and making them into fiber pads, to obtain uniform soil distribution. The K/S values for the chopped fiber pads may then be compared with those of the original fabrics and an index of nonuniformity computed. This will show the type of orthogonal nonuniformity of soil distribution that is present in the test specimen and give an estimate of its magnitude. Planar nonuniformity is, of course, the rule in soiling under service conditions except possibly for the case of soil redeposition during laundering and dry-cleaning. Orthogonal nonuniformity has also been reported (28)[2] and occurs almost universally in soiled fabrics, as the test results show.

The particle size and shape of the soil (specific absorbency.)—The theoretical analysis of this variable shows that it is a very difficult factor to evaluate or control. No data are available as to changes of specific absorbency of nonuniformity of soil distribution under service conditions, but it is obvious that this factor is of potential importance.

The modes of soil binding.—The modes of binding of soil have been discussed elsewhere (7, 8, 9, 10, 27, 28, 29). Under laboratory conditions it is not difficult to control these or isolate systems where the mode of soil binding is of one type. The probability is high that in service the modes of binding of the soil are heterogenous and highly variable. Therefore, again, the results may eventually be found not to be general, but in the mean time treatment effects may be attributed directly to treatments in the case of this particular soil rather than to possible differences in soils under a less standardized condition.

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[2] Numbers in parentheses refer to Bibliography at end of this report.

PART I — DEVELOPMENT AND DESCRIPTION OF A LABORATORY DRYCLEANING UNIT

by

Jack Compton and Leo R. Hubbard

INTRODUCTION

EXPERIMENTAL

- DEVELOPMENT OF LABORATORY DRYCLEANING UNIT
- COMMERCIAL DRYCLEANING UNIT AND PRACTICE
- LABORATORY DRYCLEANING UNIT
- DRYCLEANING PROCEDURES
  - Detergency Run—Hand Rinsing Method
  - Detergency Run Followed by Filtration
  - Detergency Run and Filtration Followed by Filtration Run in Clean Solvent
- PREPARATION OF STANDARD SOILED FABRIC FOR DRYCLEANING TEST
- REFLECTANCE MEASUREMENTS OF FABRIC
- CORRELATION OF DATA OBTAINED FROM SMALL-SCALE DRYCLEANING TESTS WITH COMMERCIAL TESTS

DISCUSSION

CONCLUSIONS

INTRODUCTION

Upon initiating work on the development of more effective methods and materials for drycleaning cotton, it was found necessary to develop first a laboratory drycleaning unit that simulated the performance of commercial drycleaning plants. This chapter is concerned with a description of the laboratory unit developed.

EXPERIMENTAL

DEVELOPMENT OF LABORATORY DRYCLEANING UNIT

Before attempting to develop a laboratory drycleaning unit, it was considered essential to study commercial drycleaning units and practices. This served as a practical basis for design of equipment and procedures to be used later.

COMMERCIAL DRYCLEANING UNIT AND PRACTICE

A schematic drawing of a commercial drycleaning plant is shown in Figure 1. There are many modifications of this used in the industry, but the operating principles are similar (15). The components of this plant will be enumerated in describing a typical drycleaning cycle. The garments, weighing about 50 pounds, are placed in the washer, A, and a prepared drycleaning soap added. The washer, containing about 60 gallons of Stoddard solvent, is run without circulation of solvent for a period of 8 to 15 minutes or until, by operator's experience, the added soap has rendered the maximum detergency. Filter powder, diatomaceous earth or sweetners, is added to the washer, A, or trap, B, and the circulating pump, C, is started. The precoating of the filter screens in D may be accomplished prior to starting the filtering cycle by circulating the 40 gallons of solvent in the filter system. This is accomplished by closing valves F_2 and F_4 and opening valve F_3. Valve F_1 is a check valve. The soiled or dirty solvent and filter powder are then circulated through the filter at a rate of about 30 changes per hour, by closing valve F_3 and opening valves F_2 and F_4, until the sight glass, E_1, in the line indicates that the solvent from the washer is clear. This requires about 20 minutes. Some plant procedures give additional circulating time after the solvent in sight glass, E_1, seems to clear. Sight glass, E_2, is placed in the line to see the effect of the filter on the clarity of the solvent. At the end of this time, the solvent is pumped out of the washer and the garments removed for drying in a closed cabinet.

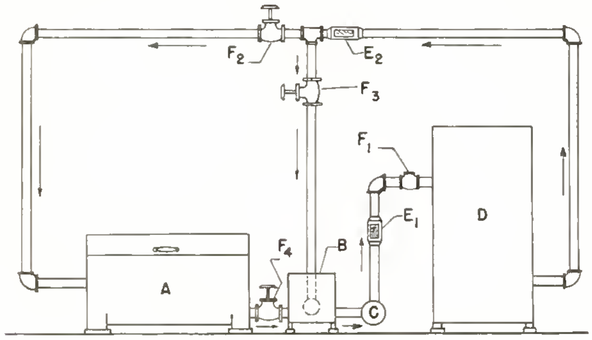

Figure 1. *Schematic drawing of a Commercial Dry Cleaning Plant.*

The Stoddard solvent may be replaced by carbon tetrachloride or perchloroethylene (Perk). The time of treatment is usually shorter when using chlorinated hydrocarbon solvents.

LABORATORY DRYCLEANING UNIT

A review of the various types of equipment available on the market for making laboratory wash tests in water systems indicated that the

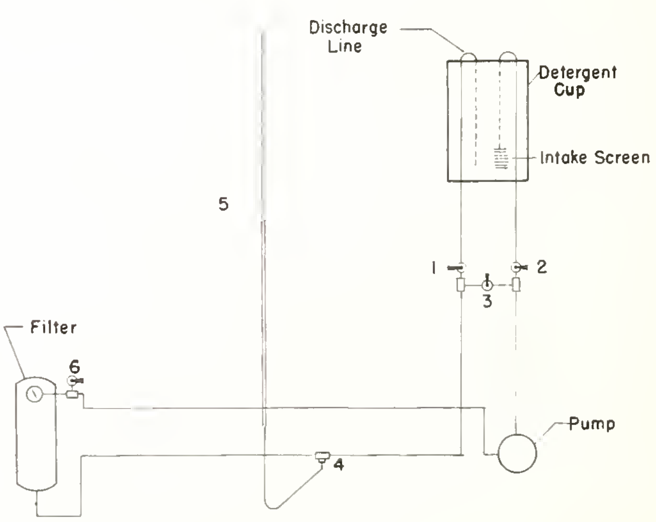

Figure 2. *Schematic drawing of Laboratory Dry Cleaning Filtration Unit.*

Terg-O-Tometer (39) possessed the performance characteritics needed for the primary component of the laboratory drycleaning unit. A filtration unit was designed to work in conjunction with the Terg-O-Tometer. A schematic drawing of the unit is shown in Figure 2 and a photograph in Figure 3. The filters (Figure 4, A and B) were constructed from conventional automobile motor oil filter shells in which the usual cartridges are replaced with stainless steel cartridges of the same dimensions. This was covered with a 200-mesh stainless steel wire cloth to give a surface approximately one-half square foot in area, (Figure 4, A). This filter area for one liter of solvent in the Terg-O-Tometer cup corresponds to the solvent-filter area found in commercial equipment.

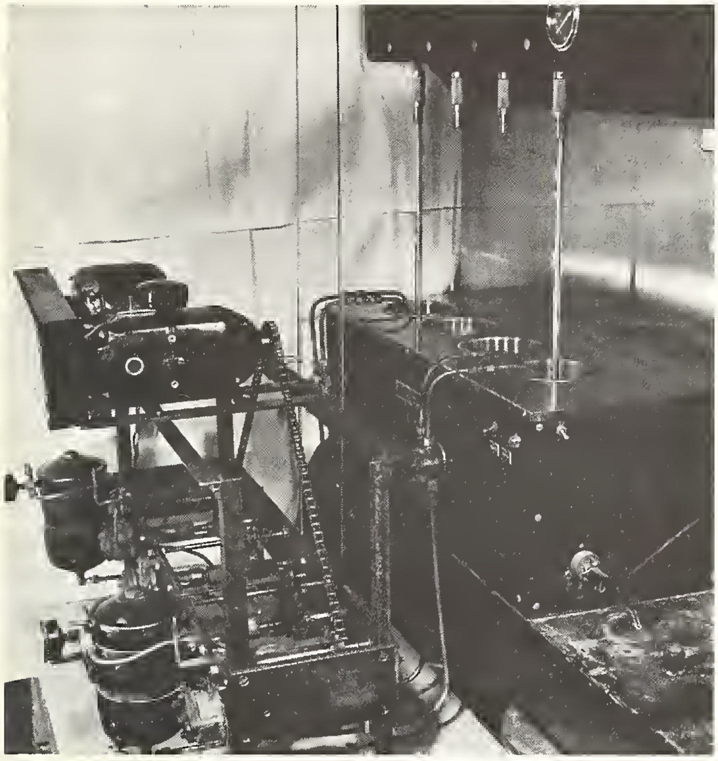

Figure 3. *Photograph of Laboratory Dry Cleaning Unit with two filtration and detergency cups of Terg-O-Tometer in operation.*

To prevent the intake line of the pumps from picking up the fabric from the drycleaning solvent in the Terg-O-Tometer cups, small, fine mesh, wire strainers were attached to the ends of the immersed portion of the suction line, (Figure 4, B).

Varying solvent flow rates were made possible by use of internal gear pumps operating at various speeds in conjunction with a hydraulic transmission, (Figure 5). A clutch was installed on each pump drive so that it was possible to stop or start each pump independently,

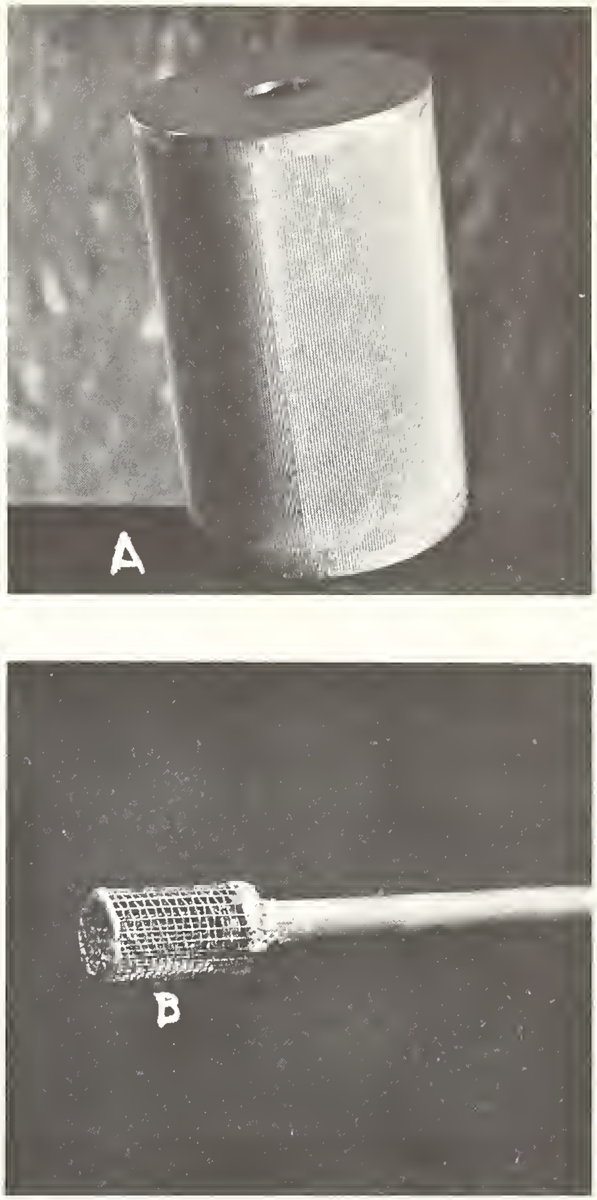

Figure 4. *Photographs of Filter Componentss*
A. Stainless steel filter cartridge covered with 200-mesh screen
B. Fine-mesh wire strainer for intake line to pump

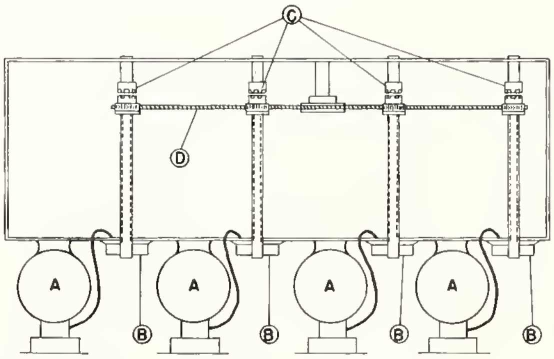

Figure 5. *Schematic drawing of Filtration Component of the Laboratory Dry Cleaning Unit Showings (A) Filters, (B) Pump, (C) Clutch and (D) Drive Chain*

thereby permitting varying time of solvent circulation. To control the filtration rate, a T was placed in the filter discharge line and this connected to a 4-foot length of 6-millimeter glass tubing, (Figure 2). The back pressure caused by the fittings, elbows, and such, between the T and the solvent in the detergent cup caused the solvent level in the glass tube to vary with the changes in the solvent flow rate. The glass tube was marked at the pressure levels corresponding to flow rates of 20, 30, 40, 60, and 80 solvent changes of the detergent bath per hour. This arrangement permitted the solvent flow rate to be controlled by varying the pump speed to compensate for filter back pressure and other variables affecting the flow rate.

By installing a valve system, (Figure 2), between the filtration unit and the detergent cup, it was possible to bypass the detergent cup and obtain continuous operation of the pump and filter. This made it possible to maintain a cake on the filter at all times, thus eliminating the complicating effects of cloudy solvent being discharged into the detergent cup during runs.

Since the seal between the mechanism on the interior of the cup and the interior filter shell was found to be unsatisfactory, a1-½″ x 1-½″ x ⅛″ square of aluminum sheeting was bored and threaded to fit the center part of the filter. When this plate was screwed down against the top of the filter core and the top placed on the unit in the usual manner, a satisfactory seal was obtained.

To charge the filtration unit, the detergent cup was filled almost full with the solvent or solvent-additive mixture; then, with valves (1) and (2), Figure 2, in the open position and valve (3) closed, the pump was started. Valve (6) was then opened and a slight vacuum applied to cause the solvent to syphon over into the detergent cup on the intake line and thence to the pump. All the air was displaced from the system after a few minutes. Solvent was added as needed to maintain a liquid depth of 3-⅝ inches in the detergent cup, corresponding to a volume of 1 liter when the agitator of the Terg-O-Tometer was in place. Slightly over 2,500 milliliters of solvent were required to fill one complete unit. This resulted in a ratio of total solvent in the detergent cup to that contained in the filter of 1:1.5, which is similar to that used in commercial drycleaning plants.

After the system was filled with solvent, 20 to 25 grams of Hyflo Super-Cel[3] were added to the solvent in the detergent cup under light agitation while the pump was in operation. Within a few minutes the filter cake was formed on the filter, and the solvent in the detergent cup cleared. If air continued to emit from the discharge line into the detergent cup, this was stopped by tightening the union in the intake line at the top of the detergent cup.

DRYCLEANING PROCEDURES

Detergency Run—Hand Rinsing Method

Four soiled and four unsoiled swatches, 6 x 6 inches, were placed in 1 liter of Stoddard solvent, with or without additive, contained in the detergency cup of the Terg-O-Tometer, and agitated for 10 minutes at room temperature at 150 cycles per minute. The swatches were then removed from the bath and rinsed by hand in 1 liter of clean solvent, care being taken to keep the rinsing procedure as uniform as possible for all tests. The swatches were removed from the last rinse, centrifuged at 2,300 r.p.m. for 1 minute in an 8-inch-diameter basket centrifuge to remove excess solvent, and dried on brass rods in a forced-draft oven at 70° C. for a minimum time of 30 minutes. The swatches were then removed from the oven and the reflectances determined.

Detergency Run Followed by Filtration

When detergency runs were made in which a soap run without filtration was made prior to filtration, valves (1) and (3), Figure 2, were opened and valve (2) closed. To start the filtration action in the detergency cup, valve (2) was opened and valve (3) closed. Approximately 5 grams of hyflo-Super-Cel were added to the cup at this time for each run. This procedure was patterned after plant practice. At the end of each test, the solvent in the cup was brought back to a volume of 1 liter as determined by the depth.

Detergency Run Followed by Filtration Followed by Filtration Run in Clean Solvent

Two drycleaning units were used in this procedure. One contained the drycleaning solvent-additive mixture, whereas the other contained clean solvent with no additive. The test swatches were introduced as in the detergency run-hand rinsing method and run in the first unit with filtration for a given time, such as 25 minutes, with no initial soaping time, the swatches were removed, centrifuged, and placed in the clean solvent with filtration for a given time, such as 5 minutes. This procedure was patterned after commercial plant practice when 4 percent soap is used in the detergency run.

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[3] The mention of trade products does not imply that they are recommended or endorsed by the Department of Agriculture over other companies and trade products not mentioned.

PREPARATION OF STANDARD SOILED FABRIC FOR DRYCLEANING TESTS

The fabric used was desized, kiered, and bleached 80 x 80 printcloth. The standard soiled fabric was prepared by tearing 2-yard lengths into 6-inch strips lengthwise and padding on a lamp black dispersion in water. It was found that one pass through the dispersion gave reproducibly soiled fabric with a reflectance of 38.2 ± 1.0%, whereas the unsoiled fabric had a reflectance of 86.5 ± 1.5%.

The lamp black stock dispersion was prepared by pasting 200 grams of Germantown lamp black with 100 milliliters of a 10% Daxad solution, adding 1,700 milliliters of water and ballmilling the mixture overnight (28, 40). Thirteen milliliters of the stock dispersion were added to 1 liter of tap water under good stirring immediately prior to soiling.

Two strips of fabric were passed through the padder at each soiling operation. The level of the soil dispersion was checked and brought back to the 1-liter volume mark with prepared soil dispersion after each fabric soiling. The soiled fabric was air-dried at room temperature for at least 4 hours, and usually overnight. The soiled strips were then cut into swatches 6 inches long. Eight swatches of the soiled fabric weighed 20 ± 0.5 grams, so that in the detergency studies the weight ratio of cloth to solvent was 1:50.

REFLECTANCE MEASUREMENTS OF FABRIC

Fabric reflectance measurements were made (29) before and after the drycleaning bath, on both the soiled and unsoiled fabric swatches in order to assess soil removal and redeposition. Reflectance values were obtained using a Photovolt Reflectometer, model 610, a green filter, zero needle setting, and National Bureau of Standards standard reflectance plates (35). Four soiled swatches were stacked on a white background and five readings taken on one side with the previously read swatch being placed consecutively in the number four position. The average of the 20 readings is that reported. The reflectances of unsoiled fabric swatches placed in the bath with the soiled swatches during a run were determined in the same manner. The reflectance of the soiled fabric was found to be about the same on each side.

CORRELATION OF DATA OBTAINED FROM SMALL-SCALE DRYCLEANING TESTS WITH COMMERCIAL TESTS

Several tests were designed to determine whether the removal and redeposition of soil with cotton fabric when using the small-scale laboratory drycleaning unit was comparable to that obtained in commercial drycleaning units. The cooperation of several drycleaning

Table 1.—Commercial drycleaning procedures used on standard soiled test swatches and unsoiled swatches attached to garments before and after drycleaning in Stoddard solvent.

Plant	Process [1]	Formulation	Filter aid	Wash time, min.	Filtration time, min.
A	charged	4% Street's 886 + 0.2% water [2]	hyflo super-cel	10	20
B	batch	0.1% alrolene 70 + 0.2% water	do.	15	20
C	do.	0.1% Soltex + 0.2% water	D. C. Filtrol	10	20
D	do.	0.1% Filt-R-Out Conc. 0.2% water	do.	10	20

[1] Extractor rinse after filtration run.

[2] Introduced as an emulsion (1 part Anolite, 24 parts water, 24 parts Stoddard solvent) ¾ oz./lb. clothes.

plants was obtained. The procedures used in these plants, along with the average soil removal and soil redeposition data obtained on soiled and unsoiled swatches attached to garments cleaned in regular drycleaning runs in each plant, are summarized in Tables 1 and 2.

Using essentially the same drycleaning procedure (detergency run followed by filtration), and the formulation used in Plant A, Table 1, the detergency efficiency of 4% Street's 886 with and without added water was determined using the laboratory drycleaning unit. An alternate procedure, detergency run and filtration followed by filtration run in clean solvent, patterned after commercial drycleaning practice, was also used in obtaining detergency efficiency data with 4% Street's 886 with and without added water. The data obtained are given in Table 3.

Table 2.—Removal and redeposition of soil during the commercial drycleaning of cotton fabric with Stoddard solvent, using conditions specified in Table 1.

Plant	Number of washings	% Fabric reflectance		% Soil[1] removal
		Unsoiled	Soiled	
(Unwashed Fabric)		(86.1)	(40.2)	
A	1	84	47	34
	5	79		
B	1	83	45	23
	5	78		
C	1	82	43	15
	5	74		
D	1	84	42	10
	5	75		

[1] See Part 2 for definition of percent soil removed.

Table 3.—Detergency efficiency of 4% Street's 886 in Stoddard solvent using two procedures with and without water on soiled and unsoiled fabric.

Procedure	Number of washings	No added water			0.5 ml. added water		
		% Fabric reflectance		% Soil[1] removal	% Fabric reflectance		% Soil[1] removal
		Unsoiled	Soiled		Unsoiled	Soiled	
(Unwashed fabric)		(86.0)	(38.2)		(86.0)	(38.2)	
DRFF[2]	1	82	55	65	83	53	58
	5	79			82		
DRFF,FF RCS[3]	1	83	53	58	82	53	58
	5	80			82		

[1] See Part 2 for definition of percent soil removed.
[2] Detergency run followed by filtration.
[3] Detergency run followed by filtration followed by filtration run in clean solvent.

DISCUSSION

Commercial drycleaning systems vary considerably in equipment and procedure, Figure 1. However, in general they may be classified by the procedure used as: (1) batch and (2) charged systems (15). In batch systems the additive and water are added to the solvent in the washer and the clothes drycleaned without external circulation of the solvent. After a wash or soap run, the solvent is circulated through a filter to remove dirt and any filter aid or sweetner that may be added to the washer. Washing continues during the filtration run. The amount of detergent added to each wash run is small but the amount may build up to eventually give, in effect, a mild, charged system. The build up of detergent in the system depends largely upon the type of filter powder used.

In the charged system the concentration of drycleaning additives may be as high as 4 to 6% or as low as 0.5% and the moisture content in the range of 0.05 to 0.15%. There is danger in adding too much water to the system, although the presence of a small amount increases the detergency efficiency of most drycleaning additives. In charged drycleaning systems, the drycleaning additive is added to the entire solvent in the system, including the filter, and, after a short wash run, circulation of the solvent through the filter is started. The wash run may be eliminated entirely. Various methods are used to rinse the fabrics: (a) extraction and transfer to a washer containing clean solvent; (b) removal of the charged solvent from the washer and rinsing with clean solvent; and (c) extractor-rinse, in which the charged solvent is removed by extraction and fresh solvent is sprayed onto the fabrics as a rinse.

In the laboratory drycleaning unit, Figure 2, the various commercial drycleaning procedures may be investigated as well as experimental procedures. The versatility of the unit has been demonstrated by a preliminary investigation of a number of drycleaning variables using standard soiled and unsoiled cotton fabrics. While it is true that artificially soiled cotton fabric may not perform in drycleaning in precisely the same way as naturally soiled fabric (12), nevertheless it behaves well enough to permit its use for the preliminary evaluation of drycleaning procedures and formulations. Nongrease-containing carbon black soil was used as the soiling agent for cotton fabric to eliminate the influence of grease on detergency and redeposition of soil in nonaqueous systems. In work reported by the National Institute of Cleaning and Dyeing it has been found that soil removal from cotton is dependent on the carbon black concentration of the soiling mixtures and increases as the soil concentration increases (23). The soiled cotton fabric reflectance of 38.5% was chosen after detergency tests in the laboratory drycleaning unit using commercial drycleaning soaps gave soil removal comparable to that found in commercial practice under similar conditions, as determined by the light transmittance (3) of the drycleaning solvent following detergent runs. From reflectance measurements it would appear that soil removal is somewhat greater with the laboratory unit than in commercial units but the two can be made comparable by controlling the severity of agitation and other processing variables, if this is desired. It is recognized that reflectance measurements of soiled fabric are not always a reliable indicator of detergency efficiency (39, 40), however, under comparable conditions they can be used for the preliminary evaluations of both detergency procedures and formulations.

By attaching soiled and unsoiled swatches of cotton fabric to garments during commercial drycleaning, Tables 1 and 2, it was found that soil removal and redeposition varied considerably. In general, the charged system was more effective than the batch systems investigated. From this limited survey, however, the need by the industry for more effective procedures and formulations for removing soil and preventing its redeposition was shown. To determine whether two of the procedures used with the laboratory drycleaning unit compared favorably with the detergency efficiency of commercial drycleaning plants, a series of runs was made using the drycleaning soap, Street's 886, with and without added water in the systems, Table 3. In general, soil removal and prevention of redeposition were greater in the laboratory unit than found in commercial practice, but the data were sufficiently close to give assurance that the unit could be used for evaluating procedures and formulations. The influence of the drycleaning procedure used is important, since it was found in the absence of added water that a wash run preceding filtration (detergency run followed by filtration), was more effective than when washing was carried on during filtration, Table 3. In the presence of water, however, there was no difference in the extent of soil redeposition on a single run. After five consecutive runs the accumulative redeposition is less when added water is used during washing.

CONCLUSIONS

(1) A laboratory drycleaning unit has been designed and procedures developed that give results quite comparable to those used in commercial drycleaning plants.

(2) Considerable variation in detergency efficiency was found in commercial drycleaning plants. The need for more effective drycleaning procedures and formulations is indicated.

PART II — USE OF REFLECTANCE MEASUREMENTS IN DETERMINING AMOUNTS AND EFFICIENCIES OF SOIL REMOVAL

by

Jack Compton, W. J. Hart,[1] and Leo R. Hubbard

INTRODUCTION

EXPERIMENTAL

- SINGLE-CYCLE DRYCLEANING
- MULTI-CYCLE DRYCLEANING
- EQUATIONS AND CALCULATIONS

DISCUSSION

CONCLUSIONS

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INTRODUCTION

The use of reflectance measurements as a means of assessing the detergency efficiency of various laundering procedures and surfactant (8) systems is almost universal (1, 2, 11, 13, 14, 25, 31, 32, 34, 36). Although numerous attempts have been made to relate purely optical considerations to the total amount of soil or pigment in a fabric (2, 31, 32, 33, 40), the most successful of these involve the elimination of the disturbing factors of fabric and yarn structure, nonuniformity of soil distribution and orientation by the use of the chopped fiber technique (7, 8, 9, 10, 27, 28, 29). Means for assessing the detergency efficiency of various drycleaning additives and procedures have thus become available and have been used in the present study on the drycleaning of cotton fabrics.

EXPERIMENTAL

SINGLE-CYCLE DRYCLEANING

A large number of detergents were tested in single-cycle drycleaning studies by the detergency run—hand rinsing method of Part I at varying concentrations of detergent and water, Table 4. Reflectances were read before and

Table 4.—Detergent efficiency of various surfactants in Stoddard solvent as calculated by the Bacon-Smith equation using both the fabric and the chopped fiber techniques.

Detergent		H_2O liter solvent	Fabric values			Fiber pad values			NU index	
			Reflectance		Soil removed	Reflectance		Soil removed		
Name	Concentration		Unsoiled	Soiled		Unsoiled	Soiled		Unsoiled	soiled
	%	ml.	%	%	%	%	%	%		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(Unwashed fabric)	—	—	(84.0)	(37.5)	—	(81.0)	(29.0)	—	1.47	1.67
Alrolene 70	0.1	0	77	47	44	70	40	50	1.82	1.50
Do.	.5	0	79	52	59	72	46	65	1.85	1.43
Do.	1.0	0	78	52	59	72	46	65	1.74	1.43
Do.	2.0	0	78	56	70	69	48	68	2.12	1.74
Do.	1.0	1	78	56	70	71	50	72	1.90	1.54
Do.	1.0	2	79	57	71	73	50	72	1.78	1.59
Do.	1.0	4	81	60	78	75	54	79	1.91	1.57
Do.	1.0	10	83	62	79	74	52	77	2.82	1.78
Do.	1.0	20	82	62	81	74	55	81	2.20	1.63
Do.	1.0	40	82	62	81	75	55	81	2.10	1.63
Do.	1.0	80	81	60	76	78	56	82	1.41	1.25
Do.	4.0	1	74	56	69	66	50	72	2.00	1.48
Do.	4.0	2	75	56	70	66	50	73	2.00	1.49
Do.	4.0	4	76	58	73	72	51	75	1.50	1.60
Span 60	0.1	0	69	45	37	71	42	56	0.84	1.19
Do.	.5	0	80	52	61	76	46	66	1.44	1.43
Do.	1.0	0	80	52	58	77	46	65	1.36	1.39
Do.	2.0	0	80	52	58	79	46	66	1.12	1.35
Do.	4.0	0	80	52	58	78	47	67	1.32	1.31
Do.	1.0	1	80	52	58	78	50	73	1.24	1.10
Do.	1.0	2	80	55	67	78	52	76	1.24	1.21
Do.	1.0	4	80	56	68	79	53	78	1.12	1.16
Do.	4.0	1	80	53	62	80	52	76	1.04	1.07
Do.	4.0	2	80	54	65	80	52	76	1.04	1.20
Do.	4.0	4	80	57	71	80	56	82	1.00	1.07

Table 4.—Detergent efficiency of various surfactants in Stoddard solvent as calculated by the Bacon-Smith equation using both the fabric and the chopped fiber techniques.

Detergent		H_2O liter solvent	Fabric values			Fiber pad values			NU index	
			Reflectance		Soil removed	Reflectance		Soil removed		
Name	Concentration		Unsoiled	Soiled		Unsoiled	Soiled		Unsoiled	soiled
	%	*ml.*	%	%	%	%	%	%		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Naccolene	0.1	0	70	47	44	67	40	50	1.33	1.50
Do.	.5	0	74	46	39	71	40	48	1.30	1.42
Do.	1.0	0	79	50	34	75	42	55	1.50	1.60
Do.	2.0	0	80	52	58	79	46	66	1.12	1.35
Do.	4.0	0	81	51	56	77	47	67	1.55	1.27
Do.	1.0	1	80	50	55	78	44	62	1.32	1.43
Do.	1.0	2	78	51	56	74	45	63	1.33	1.43
Do.	1.0	4	72	51	56	68	45	63	1.39	1.43
Do.	4.0	1	82	54	64	78	50	73	1.55	1.28
Do.	4.0	2	82	54	65	78	50	74	1.55	1.27
Do.	4.0	4	82	56	69	78	52	76	1.48	1.32
Glyceryl	0.1	0	78	50	54	74	43	58	1.44	1.51
Mono-	.5	0	82	55	67	77	48	69	1.62	1.54
oleate	1.0	0	82	56	69	77	49	71	1.70	1.54
Do.	2.0	0	82	52	58	77	46	64	1.70	1.43
Do.	4.0	0	82	52	58	78	46	64	1.55	1.43
Oronite No. 5	0.1	0	75	48	49	70	40	50	1.45	1.65
Do.	.5	0	80	48	47	76	42	55	1.50	1.42
Do.	1.0	0	81	48	49	76	42	57	1.68	1.42
Aerosol	.1	0	66	44	35	62	35	31	1.33	1.74
O T	.5	0	70	42	24	62	34	25	1.76	1.65
Do.	1.0	0	70	44	30	64	34	27	1.51	1.74
Span 65	0.1	0	66	44	33	64	36	38	1.14	1.55
Do.	.5	0	68	45	37	68	42	54	1.04	1.22
Do.	1.0	0	70	46	21	70	44	61	1.00	1.12
Span 80	0.1	0	75	48	46	72	41	52	1.36	1.47
Do.	.5	0	76	50	51	75	43	58	1.10	1.47
Do.	1.0	0	75	47	44	75	43	58	1.00	1.26
Do.	2.0	0	77	46	42	89	48	68	.20	.94
Do.	4.0	0	75	43	28	85	45	63	.32	.89
Span 85	0.1	0	64	40	14	71	40	48	0.58	1.03
Do.	.5	0	75	45	37	80	47	67	.55	.89
Do.	1.0	0	76	56	40	74	42	55	1.16	1.26
Do.	2.0	0	80	46	42	77	42	57	1.36	1.26
Do.	4.0	0	75	46	40	74	42	55	1.10	1.26
Tween 60	0.1	0	50	40	17	48	32	17	1.10	1.65
Do.	.5	0	45	29	69	50	35	31	.77	.70
Do.	1.0	0	43	23	-152	54	34	27	.53	.48
Tween 65	0.1	0	64	44	33	60	38	43	1.32	1.42
Do.	.5	0	76	51	56	76	44	61	1.11	1.52
Do.	1.0	0	77	50	55	74	46	65	1.29	1.31
Do.	2.0	0	77	50	52	74	43	58	1.30	1.47
Do.	4.0	0	78	50	54	77	44	59	1.17	1.47
Tween 80	0.1	0	48	34	-20	49	31	12	0.93	1.24
Do.	.5	0	48	29	-69	51	27	-14	.81	1.14
Do.	1.0	0	40	21	-191	46	26	-26	.73	.73
Tween 85	0.1	0	60	41	19	52	35	32	1.66	1.42
Do.	.5	0	72	48	46	70	42	57	1.09	1.34
Do.	1.0	0	72	48	48	70	44	61	1.23	1.28

after drycleaning and on both the soiled and unsoiled (redeposit) swatches. The fabric used had an original unsoiled reflectance of 84% which was changed to a value of 81% after chopping in the Wiley mill to a fiber length of 0.1—1.0 millimeter (28). Two each of the soiled swatches and the redeposit swatches were chopped in a Wiley mill, slurried with Stoddard solvent, and made into fiber pads on a buchner funnel. Three reflectance readings were made on each side of the pad and the average taken as the fiber pad reflectance. The reflectances of the standard soiled fabric were 37.5%, whereas, after chopping in the Wiley mill and making fiber pads, as described above, they were 29.0%. Duplicate fiber pads almost never showed a reflectance difference greater than 2%.

Table 5.—Detergent efficiency of various drycleaning additives in Stoddard solvent multi-cycle tests as calculated by the Bacon-Smith equation using the chopped fiber technique.

Detergent	No. of cycles	Fabric values			Fiber pad values			NU index	
		Reflectance		Soil removed	Reflectance		Soil removed		
		Unsoiled	Soiled		Unsoiled	Soiled		Unsoiled	Soiled
		%	%	%	%	%	%		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(Unwashed fabric)	—	(84.0)	(37.5)	—	(81.0)	(29.0)	—	—	—
None	1	62	38	6	58	30	4	1.23	1.70
Do.	2	58	40	12	54	30	6	1.37	1.76
Do.	4	56	39	9	51	30	6	1.35	1.71
Do.	8	54	39	9	49	32	15	1.39	1.56
Alrolene 70	1	80	53	62	80	49	71	1.00	1.27
(0.5%)	2	78	56	70	76	52	76	1.23	1.36
Do.	4	80	61	78	77	54	80	1.36	1.57
Do.	8	80	62	79	78	57	84	1.32	1.34
Naccolene conc.	1	80	50	55	76	44	59	1.54	1.52
(0.5%)	2	80	52	59	78	46	65	1.16	1.43
Do.	4	80	54	62	78	49	71	1.24	1.27
Do.	8	79	55	67	76	50	72	1.36	1.40
Glyceryl monooleate	1	82	54	64	80	48	70	1.30	1.39
(0.5%)	2	82	56	70	80	50	71	1.30	1.58
Do.	4	82	58	72	80	52	76	1.20	1.45
Do.	8	81	59	75	80	53	78	1.18	1.45
Sodium oleate [1]	1	78	52	58	76	48	68	1.16	1.27
(0.5%)	2	80	52	60	80	52	77	0.95	1.00
Do.	4	78	54	63	79	54	80	0.90	0.97
Do.	8	78	54	64	80	56	82	0.85	0.88
Ethanolamine oleate	1	80	52	60	80	47	67	1.04	1.39
(0.5%)	2	80	54	66	80	50	72	1.00	1.36
Do.	4	78	55	67	78	50	72	1.00	1.40
Do.	8	78	56	69	77	51	75	1.10	1.36
Acto 450	1	78	52	59	78	45	63	1.14	1.51
(0.5%)	2	80	56	68	80	51	75	1.13	1.32
Do.	4	81	60	78	80	54	80	1.18	1.52
Do.	8	80	61	78	78	56	82	1.16	1.42
Aerosol OT	1	72	46	42	68	40	48	1.26	1.50
(0.5%)	2	72	46	38	69	39	46	1.24	1.46
Do.	4	72	47	44	69	42	54	1.30	1.38
Do.	8	72	48	47	70	42	54	1.24	1.45

[1] 70% neutralized

MULTI-CYCLE DRYCLEANING

Multi-cycle drycleaning tests were run on a number of detergents, Table 5. Four standard soiled and four unsoiled swatches of cotton printcloth were given a 10-minute run in the Terg-O-Tometer operating at 150 cycles per minute, rinsed by hand, centrifuged, dried, and the reflectances determined after 1, 2, 4, and 8 cycles with no soiling between drycleanings. Two of each of the swatches were then chopped, slurried, and made into fiber pads and the reflectances again determined as described above.

EQUATIONS AND CALCULATIONS

The reflectance values, columns 4, 5, 7, and 8 of Table 4 and columns 3, 4, 6, and 7 of Table 5 were converted by the Kubelka-Munk Relationship to K/S values which were used in the Bacon-Smith Equation to estimate percent soil removal, columns 6 and 9 of Table 4, and columns 5 and 8 of Table 5. In the interest of conserving space individual K/S values are not reproduced here. The Bacon-Smith Equation estimates the percent of soil removed by:

$$\%\ \text{soil removed} = 100\,\frac{K/S_{\text{soiled fabric}} - K/S_{\text{washed fabric}}}{K/S_{\text{soiled fabric}} - K/S_{\text{unsoiled fabric}}} \qquad [1]$$

The K/S values are related to reflectance by the relationship of Kubelka-Munk (32),

$$K/S = \frac{(1-R)^2}{2R} \qquad [2]$$

where R is the light reflectance as a decimal fraction, K is the light absorption coefficient, and S is the light scattering coefficient. The assumption made in this equation that K is proportional to the amount of light absorbing material is not always true, and thus errors may result from the use of the equation. The conditions and the factors that affect the conditions wherein this equation is valid have been given detailed consideration by Hart and Compton (28) and others (33). Of the two major variables; namely, nonuniformity of soil distribution and changes in specific absorbence, the former may be eliminated by chopping the test fabric in a Wiley mill or similar device, slurrying the chopped material, and making a fiber pad. This procedure also gives useful information as to the type or magnitude of nonuniformity of soil distribution existent in the fabric, if the K/S values for fabric and chopped fiber pad are compared. Changes in specific absorbence may be detected by determining the K/S values for soiled fabric and redeposit swatches and adding to these the K/S value corresponding to the soil content of the bath (29, 41).

Since the K/S values are indices to the soil contents of given systems and the calculation of these from the Kubelka-Munk Equation (equation [2]) is time-consuming, tables have been prepared for reference (30). Bacon and Smith (2) have also developed a monogram that permits equation [1] to be solved directly from reflectance values, but this is a small-scale figure and covers a limited range of values.

The ratios of K/S values were computed for the fabric reflectances and fiber pad reflectance readings to obtain indices of orthogonal nonuniformity (28) which were entered in columns 10 and 11 of Table 4 and columns 9 and 10 of Table 5. The index is calculated as:

$$I_{NU} = \frac{(K/S)_{CWF}}{(K/S)_{WF}} \qquad [3]$$

where $(K/S)_{CWF}$ = the K/S value for the chopped fiber pad prepared from soiled washed fabric,

$(K/S)_{WF}$ = the K/S value for the soiled washed fabric, and

I_{NU} = index of orthogonal nonuniformity.

If I_{NU} is greater than 1.1, type C distribution is present; or, in other words, the soil tends to be concentrated in the interior of the fabric. If I_{NU} is between 0.9 and 1.1, type B, or uniform soil distribution, is the case. For I_{NU} values less than 0.9, type A distribution occurs, or soil is concentrated near the surface of the fabric (29).

The equation of Bacon and Smith [1] is commonly used for calculating the percentage of soil removed from soiled fabrics in the evaluation of detergents and washing procedures. In this equation,

$$\%\ \text{soil removed} = 100 \times \frac{(K/S)_{SF} - (K/S)_{WF}}{(K/S)_{SF} - (K/S)_{0}} \qquad [1]$$

where $(K/S)_{SF}$ = the K/S value for the soiled fabric,

$(K/S)_{WF}$ = the K/S value for the soiled and washed fabric, and

$(K/S)_{0}$ = the K/S value for the unsoiled fabric

Similarly the equation of Bacon and Smith [1] is used in this work for calculating the percentage of soil removed from drycleaned soiled fabric chopped in a Wiley mill to eliminate nonuniformity of soil distribution effects. In this equation,

$$\%\ \text{soil removed} = 100 \times \frac{(K/S)_{CSF} - (K/S)_{CWF}}{(K/S)_{CSF} - (K/S)_{CO}} \qquad [1b]$$

where $(K/S)_{CSF}$ = the K/S value for chopped soiled fabric,

$(K/S)_{CWF}$ = the K/S value for the washed chopped soiled fabric,

$(K/S)_{CO}$ = the K/S value for the chopped unsoiled fabric.

To illustrate the calculation involved in the foregoing relationships consider the first two lines of data in Table 4.

For unsoiled unwashed fabric:

$$(K/S)_O = \frac{(1-0.84)^2}{2(0.84)} = 0.015 \text{ for fabric,}$$

$$(K/S)_{CO} = \frac{(1-0.81)^2}{2(0.81)} = 0.022 \text{ for chopped fiber pad.}$$

For soiled unwashed fabric:

$$(K/S)_{SF} = \frac{(1-0.375)^2}{2(0.375)} = 0.521 \text{ for fabric,}$$

$$(K/S)_{CSF} = \frac{(1-0.290)^2}{2(0.290)} = 0.869 \text{ for chopped fiber pad.}$$

For unsoiled fabric washed once with 0.1% Alrolene:

$$(K/S)_{OW} = \frac{(1-0.77)^2}{2(0.77)} = 0.034 \text{ for fabric,}$$

$$(K/S)_{COW} = \frac{(1-0.70)^2}{2(0.70)} = 0.062 \text{ for chopped fiber pad.}$$

For soiled fabric washed once with 0.1% Alrolene:

$$(K/S)_{WF} = \frac{(1-0.47)^2}{2(0.47)} = 0.299 \text{ for fabric,}$$

$$(K/S)_{CWF} = \frac{(1-0.40)^2}{2(0.40)} = 0.450 \text{ for chopped fiber pad.}$$

The indices of nonuniformity as calculated by [3] for the unwashed fabric and the first soiled fabric (0.1% Alrolene) of Table 4 are:

$$I_{NU} = \frac{(K/S)_{CO}}{(K/S)_O} = \frac{0.022}{0.015} = 1.47 \text{ for unsoiled unwashed fabric}$$

$$I_{NU} = \frac{(K/S)_{CSF}}{(K/S)_{SF}} = \frac{0.869}{0.521} = 1.67 \text{ for soiled unwashed fabric}$$

$$I_{NU} = \frac{(K/S)_{CSF}}{(K/S)_{SF}} = \frac{0.062}{0.034} = 1.82 \text{ for unsoiled washed fabric}$$

$$I_{NU} = \frac{(K/S)_{CWF}}{(K/S)_{WF}} = \frac{0.450}{0.299} = 1.50 \text{ for soiled washed fabric}$$

Nonuniformity values are entered in columns 10 and 11 of Table 4 and columns 9 and 10 of Table 5.

Since the K/S values for unsoiled unwashed and soiled unwashed fabric do not change, equation [1a] reduces for the data presented in Tables 4 and 5 to:

$$\%\ \text{soil removed, fabric} = 100 \times \frac{0.521 - (K/S)_{WF}}{0.521 - 0.015}$$

$$= 100 \times \frac{0.521 - (K/S)_{WF}}{0.506} \qquad [1c]$$

and equation [1b] similarly reduces to:

$$\%\ \text{soil removed, chopped fiber} = 100 \times \frac{0.869 - (K/S)_{CWF}}{0.869 - 0.022}$$

$$= 100 \times \frac{0.869 - (K/S)_{CWF}}{0.847} \qquad [1d]$$

From these formulas the percent soil removal by 0.1% Alrolene as estimated from K/S values for fabric and fiber pad are:

$$(100)\,\frac{0.521-0.299}{0.521-0.015} = 44\% \text{ for fabric and,}$$

$$(100)\,\frac{0.869-0.450}{0.869-0.022} = 50\% \text{ for chopped fiber pad.}$$

Soil removal percentages were estimated from both fabric reflectance and pad reflectance readings and entered in columns 6 and 9 of Table 4 and columns 5 and 8 of Table 5. These results, as obtained by the Bacon and Smith Equation, are somewhat different from those that would be obtained using the linear reflectance equation of Harris (26). In the equation of Harris reflectance values are used instead of K/S values. Thus

$$\%\ \text{soil removed} = 100 \times \frac{(R)_{WF} - (R)_{SF}}{(R)_O - (R)_{SF}} \qquad [4]$$

where $(R)_{WF}$ is the reflectance of the washed soiled fabric,

$(R)_{SF}$ is the reflectance of the original soiled fabric, and

$(R)_O$ is the reflectance of the unsoiled fabric.

The large inherent error involved in the use of equation [4] is shown in Figure 6, for the case of a fabric containing an ideal pigment with $(R)_O = 85\%$, soiled to a reflectance, $(R)_{SF}$, of 40%, and theoretically washed to different reflectances, $(R)_{WF}$.

Lack of agreement in percent soil removed for apparently identical reflectance values in Tables 4 and 5 may be attributed to the following facts: (1) The percentages were computed from reflectance values recorded to one more decimal place than here shown; (2) each treatment originally had its own individual check values for unwashed fabric—and these varied slightly.

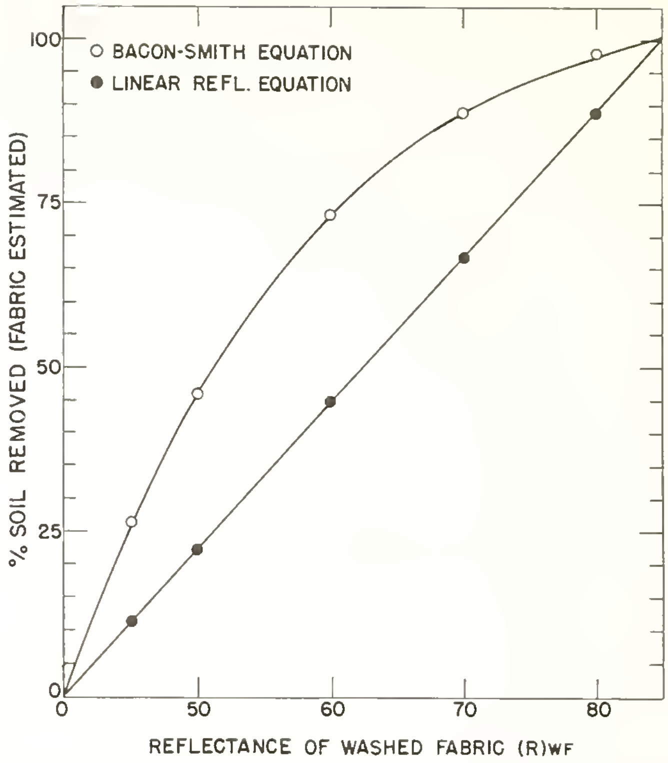

Figure 6. *Comparison of equations of Bacon-Smith and Harris for estimating percent soil removed*

DISCUSSION

Soil distribution is given extensive consideration in this work. When soil distribution is homogenous, K/S values are directly proportional to soil content, providing specific absorbence does not change. It is possible, by chopping the test fabrics and making them into fiber pads, to obtain uniform soil distribution. The K/S values for the chopped fiber pads may then be compared with those of the original fabrics and an index of nonuniformity, I_{NU}, computed by [3]. This index shows the type of orthogonal nonuniformity of soil distribution (28) that is present in the test specimen and gives an estimate of its magnitude.

Planar nonuniformity is, of course, the rule in soiling under service conditions except possibly for the case of soil redeposition during laundering and drycleaning. Orthogonal nonuniformity has also been reported (29) and occurs almost universally in soiled fabrics, as the test results show. The predominance of type C distribution in both soiled and redeposit swatches is evident in Tables 4 and 5. It is suggested that this is a result of the drying process, as the shrinking film of bath liquor tends to carry unattached soil particles to the interior of the fabric.

Since chopped fiber pads do have homogenous soil distribution, and assuming that specific absorbence does not change (which may be true within a single detergent system), the K/S values of chopped fiber pads are indices of the amount of soil present. They may, therefore, be used as in the Bacon and Smith equation [1] and [lb] to estimate the percent of soil removed from the swatches. From Figure 6 it is evident that there would be considerable error in using estimates of soil removal based directly on reflectance readings by means of the Harris equation [4]. For this reason all detergency efficiency values reported in this study are based on the Bacon and Smith equation using the Kubelka-Munk K/S values.

The estimation of percent soil removal based on chopped fiber pads seems justified, but preparation of the pads is a time consuming procedure. It is desirable to avoid this procedure when possible. Whether one could dispense with the chopping process and use, instead, reflectance values obtained directly from fabrics would depend on the frequency, magnitudes, and seriousness of the errors which might result from this procedure. Percent soil removal values based on *fabric* reflectance are plotted in Figure 7 against similar values based on fiber *pad* reflectance for all detergent systems in Tables 4 and 5 having soil removal values in the range of 45 to 65 percent based on fabric reflectances using the Bacon-Smith equation. Figure 7 indicates that in this range the percent soil removal as estimated from fiber pad reflectance can probably be estimated most of the time without seriously large errors by adding 6 percentage points to the soil removal value obtained from fabric reflectance readings.

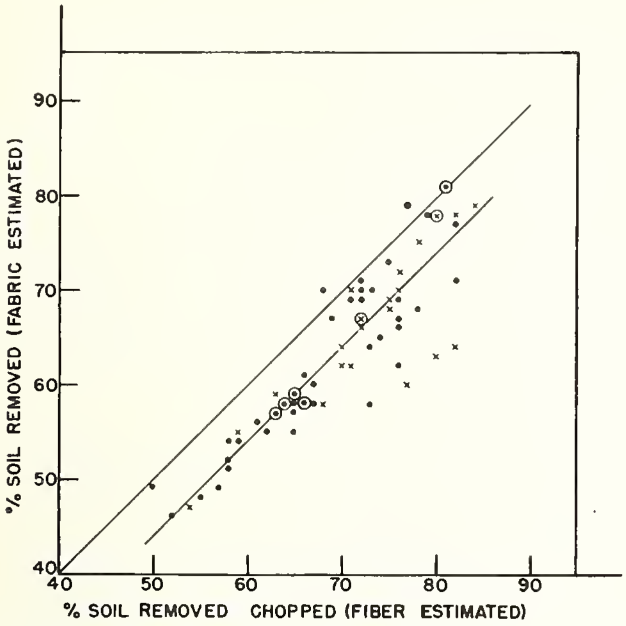

Figure 7. *Relationship of soil removal values based on fabric reflectances to values based on chopped fiber pads when restricted to fabric estimates of 45% or more.*

For soil removal values lower than 45% an investigator would probably wish to obtain chopped fiber reflectance values as a check on type of soil distribution. For values above 65% the investigator would probably wish to check reflectances of chopped fiber pads to obtain better estimates of the efficiency of the detergency system. When reflectance values of chopped fiber pads are obtained one can use the Bacon-Smith equation [1]. If the values are above 65% the investigator could use the equation of Harris [4] as modified below:

$$\% \text{ soil removed} = 100 \; \frac{(R)_{CWF} - (R)_{CSF}}{(R)_{CO} - (R)_{CSF}} \quad [5]$$

This modification is based on calculations not shown here but which indicated that, in general, the percent soil removal calculated directly from the reflectances of the fiber pads was 31.5 ± 2.5% lower than when calculated from K/S values. It is possible that this relationship might vary in other detergent-solvent systems.

CONCLUSIONS

Percent soil removal is a desirable way of measuring detergency efficiency. Percent soil removal is estimated more exactly using the K/S values of the Kubelka-Munk equation than using fabric reflectance values directly. Percent soil removal is also estimated more exactly using chopped fiber pad reflectance readings than fabric reflectance readings. The discrepancy between these two methods may be approximately corrected for fabric derived soil removal percentages between 45% and 65% by adding 6 percentage points. Chopped fiber pads should be prepared for systems yielding soil removal percentages outside this range.

PART III — EVALUATION OF DRYCLEANING MATERIALS AND PRACTICES FOR COTTON FABRIC SOILED WITH NONGREASY WATER-INSOLUBLE SOIL

by

JACK Compton and Leo R. Hubbard

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    - Mixed Solvent Drycleaning Systems
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INTRODUCTION

There is need for general and specific knowledge in drycleaning of cotton. In particular information is needed about solvents, additives and their concentrations, temperatures, lengths of washing and filtering cycles, and the effect of added water. The introduction of water into the drycleaning solvent in emulsified form is common practice in a large majority of drycleaning plants. The amount of water added varies considerably but is most often in the range of 1 to 3 percent by weight of the garments as received. Although it is known that fabrics pick up some of the added water (5, 6), no data have been available regarding the moisture equilibrium attained by cotton fabrics in drycleaning systems. In the case of wool, it has been shown that predrying deters soil removal, whereas, if the fabric is allowed to regain moisture before drycleaning, the soil is more easily removed (4, 6). It has also been found that the minimum redeposition of soil occurs when rayon fabric is preconditioned at a relative humidity of 40 to 60 before drycleaning, which corresponds to a moisture regain of 8.8% to 12.2% (16). It would thus seem of value to study in detail the role of water in the drycleaning of cotton fabric. This chapter reports on experiments yielding information on drycleaning materials and practices.

EXPERIMENTAL

CONVENTIONAL DRYCLEANING SOLVENTS

The two primary drycleaning solvents used commercially are Stoddard solvent and perchloroethylene. At the present time about 80 percent of the total drycleaning solvents used is Stoddard solvent, although the use of chlorinated hydrocarbons is gaining in favor because of their nonflammable properties. Detergency efficiencies were evaluated for these solvents using various additives with and without added water. These tests used the procedure of a detergency run followed by filtration as described in Part I. Specifically there was a 10-minute soap run followed by a 20-minute filtration run at a flow rate of 40 changes per hour. The drycleaning additives studied were glyceryl monooleate (GMO) and Calcharge in a bath concentration of 0.5%, in the absence and presence of 0.5 milliliter of water per liter of solvent. The results obtained are given in Table 6.

Table 6.—Effect of Stoddard solvent and perchloroethylene as drycleaning solvents on the removal and redeposition of soil from cotton fabric using a 10-minute wash time and a 20-minute filtration time at a solvent flow rate of 40 changes per hour in the presence and absence of moisture using glyceryl monooleate and calcharge at 0.5% concentration.

Solvent	Additive	H_2O per liter of solvent	Fabric reflectance		Soil removed
			Unsoiled	Soiled	
		ml.	%	%	%
(Unwashed fabric)			(84.7)	(39.3)	
Stoddard solvent	None	0	71	47	39
	GMO	0	83	57	68
	GMO	0.5	83	57	68
	Calcharge	0	79	51	52
	Calcharge	0.5	75	50	49
Perchloroethylene	None	0	64	47	37
	GMO	0	80	58	69
	GMO	0.5	72	58	69
	Calcharge	0	76	54	59
	Calcharge	0.5	70	50	49

OTHER SOLVENTS FOR DRYCLEANING

Perchloroethylene has been the most widely adopted drycleaning solvent of the chlorinated hydrocarbons. Because of the scarcity of chlorinated hydrocarbons during periods of national emergency, however, most drycleaners are reluctant to discard the more readily available Stoddard solvent but are ever hopeful of finding a cheap nonflammable substitute. In continuing the series of studies on the drycleaning of cotton fabric it was of interest to determine if other organic solvents were as efficient drycleaning solvent media as the conventional solvents, Stoddard solvent, and perchloroethylene. To obtain information on this, 15 organic solvents (Table 7) selected for their functional groups were evaluated as drycleaning solvents.

Table 7.—Organic solvents evaluated as dry cleaning solvent for soiled cotton fabric.

Product	Source	Classification
cyclohexanone	Distillation Products Industries	cyclic ketone
tetrahydronapthalene	Eastman Kodak Company	aromatic hydrocarbon
n-butyl alcohol	Carbide and Carbon Chemicals Co.	primary alcohol
diacetone alcohol	do.	ketone alcohol
ethyl acetoacetate	do.	keto-ester
alpha pinene	Hercules Powder Co.	terpene
dichloroethyl ether	Carbide and Carbon Chemicals Co.	chlorine substitute ether
cellosolve acetate	do.	butyl ether-ester
n-butyl ether	do.	butyl ether
isopropyl acetate	do.	branched ester
l-chloro-l-nitro-propane	Commercial Solvents Co.	chloro-nitro-aliphatic
di-isobutyl ketone	Carbide and Carbon Chemicals Co.	branched ketone
nitroethane	Commercial Solvents Co.	nitro-aliphatic
Cellosolve solvent	Carbide and Carbon Chemicals Co.	ether alcohol
l-nitropropane	Commercial Solvents Co.	nitro-aliphatic

Single Solvent Drycleaning Systems

The drycleaning procedure for the 15 selected solvents was the detergency run—hand rinsing method described in Part I. Reflectances were read on the soiled and clean fabric swatches before and after drycleaning. The percent soil removed from the soiled cotton was calculated from fabric reflectance measurements using the Kubelka-Munk Relationship and the Bacon-Smith equation. The reflectances and soil removal values obtained for the single solvent systems are summarized in Table 8.

Table 8.—Effects of various experimental dry cleaning solvents on soil removal and redeposition as affected by using glyceryl monooleate additive with and without added water.

	Concentration of additive (%) and ml. of water per liter of solvent				
	No additive		1 % glyceryl monooleate		
Additive	0 ml. H_2O	1 ml. H_2O	0 ml. H_2O	1 ml. H_2O	5 ml. H_2O
		Reflectance, unsoiled fabric			
	%	%	%	%	%
(Unwashed fabric)	(86.4)				
Stoddard solvent	62	62	82	82	83
Perchloroethylene	54	—	79	81	81
Cyclohexanone	77	—	74	—	76
Tetrahydronapthalene	62	—	79	—	79

Table 8.—Effects of various experimental dry cleaning solvents on soil removal and redeposition as affected by using glyceryl monooleate additive with and without added water.

Additive	Concentration of additive (%) and ml. of water per liter of solvent				
	No additive		1 % glyceryl monooleate		
	0 ml. H_2O	1 ml. H_2O	0 ml. H_2O	1 ml. H_2O	5 ml. H O
			Reflectance, unsoiled fabric		
	%	%	%	%	%
N-butyl alcohol	80	—	79	—	79
Diacetone alcohol	80	—	78	—	78
Ethyl acetoacetole	83	—	72	—	70
Alpha pinene	63	—	80	—	80
Dichloroethyl ether	80	—	70	—	56
Cellosolve acetate	71	—	81	—	80
N-butyl ether	66	—	76	—	76
Isopropyl acetate	67	—	81	—	79
1-chloro-1-nitropropane	69	—	56	—	55
Di-isobutyl ketone	79	—	82	—	82
Nitroethane	66	—	64	—	62
Cellosolve solvent	80	—	74	—	75
1nitropropane	64	—	58	—	54
			Reflectance, soiled fabric		
	%	%	%	%	%
(Unwashed fabric)	(38.4)				
Stoddard solvent	38	38	56	54	60
Perchloroethylene	39	—	55	56	61
Cyclohexanone	48	—	47	—	48
Tetrahydronapthalene	40	—	52	—	58
N-butyl alcohol	47	—	48	—	47
Diacetone alcohol	48	—	48	—	48
Ethyl acetoacetate	51	—	48	—	46
Alpha pinene	39	—	50	—	55
Dichloroethyl ether	50	—	46	—	40
Cellosolve acetate	46	—	51	—	51
N-butyl ether	40	—	50	—	51
Isopropyl acetate	44	—	50	—	50
1-chloro-1-nitropropane	47	—	40	—	40
Di-isobutyl ketone	46	—	51	—	55
Nitroethane	45	—	40	—	40
Cellosolve solvent	50	—	48	—	47
1-nitropropane	42	—	41	—	42
			Soil removed		
	%	%	%	%	%
Stoddard solvent	—9	—4	66	61	73
Perchloroethylene	4	—	64	67	76
Cyclohexanone	43	—	39	—	46
Tetrahydronaphthalene	12	—	56	—	71
N-butyl alcohol	41	—	43	—	38
Diacetone alcohol	44	—	43	—	43
Ethyl acetoacetate	51	—	43	—	37
Alpha pinene	6	—	52	—	65
Dichloroethyl ether	48	—	45	—	11
Cellosolve acetate	36	—	53	—	55
N-butyl ether	4	—	49	—	53
Isopropyl acetate	27	—	50	—	50
1-chloro-1-nitropropane	39	—	9	—	10
Di-isobutyl ketone	37	—	54	—	64
Nitroethane	35	—	12	—	11
Cellosolve solvent	50	—	42	—	42
1-nitropropane	19	—	13	—	18

Mixed Solvent Drycleaning Systems

The procedure followed was the same as described in the foregoing paragraph; but in this case instead of using single solvents the organic solvents evaluated in Table 8, having the highest detergency efficiency without additive or water, were separately mixed with Stoddard solvent and perchloroethylene in the proportion of one part of the former to 9 parts of the latter. These mixtures of ethyl acetoacetate, cellosolve solvent, and dichloroethyl ether with Stoddard solvent and perchloroethylene were evaluated as drycleaning solvents both alone, and with the 3 additives, guanidine oleate, Street's 886, and glyceryl monooleate, both in the absence and presence of 0.5 milliliter of added water per liter of solvent. The results obtained are given in Table 9.

Table 9.—The effects of ethyl acetoacetate, cellosolve solvent, and dichloroethyl ether mixtures (1:9) with Stoddard solvent and perchloroethylene on soil removal and redeposition, as affected by the additives, guanidine oleate, Street's886, and glyceryl monooleate at 1% concentration with and without added water.

Additive	H_2O liter of solvent	Solvent mixture (9:1)					
		Stoddard solvent with:			Perchloroethylene with:		
		Ethyl acetoacetate	Cellosolve solvent	Dichloroethpl ether	Ethyl acetoacetate	Cellosolve solvent	Dichloroethpl ether
	(ml.)						
				Reflectance, unsoiled fabric			
		%	%	%	%	%	%
(Unwashed fabric)	—	(87.9)					
None	0.0	61	62	61	56	57	55
Guanidine	0.0	75	66	80	80	69	82
oleate	0.5	59	54	78	75	56	77
Street's 886	0.0	79	76	82	79	77	82
Do.	0.5	66	52	80	64	56	75
Glyceryl	0.0	60	65	82	66	63	80
monooleate	0.5	79	53	83	57	58	82
				Reflectance, soiled fabric			
		%	%	%	%	%	%
(Unwashed fabric)	—	(38.5)					
None	0.0	39	39	38	40	39	37
Guanidine	0.0	57	44	48	52	49	53
oleate	0.5	38	38	58	59	42	59
Street's 886	0.0	49	48	50	51	51	50
Do.	0.5	48	38	58	50	39	56
Glyceryl	0.0	41	42	52	47	45	54
monooleate	0.5	49	39	59	38	36	60
				Soil removed			
		%	%	%	%	%	%
None	0.0	4	3	—2	7	4	6
Guanidine	0.0	68	30	45	57	45	59
oleate	0.5	—2	—2	69	73	16	71
Street's 886	0.0	47	40	49	55	52	56
Do.	0.5	46	19	70	50	1	68
Glyceryl	0.0	17	6	55	39	30	59
monooleate	0.5	48	2	71	3	16	75

EFFECTS OF VARIOUS DRYCLEANING ADDITIVES

Comparative results with various additives are reported in Tables 4 and 5 of Part II, and in Tables 6, 9, 12 13, 14, 15, 16, 17, and 19 (A, B, and C) of this part III.

Table 10.—Effects of washing and filtering times on soil removal and redeposition at a filtering rate of 40 changes per hour using 0.5% glyceryl monooleate in Stoddard solvent.

Washing time	Filtering time		
	10 Min.	20 Min.	30 Min.
(Min.)			
	Reflectance, unsoiled fabric		
	%	%	%
(Unwashed fabric)	(87.0)		
0	83	82	82
5	82	82	82
10	83	83	83
	Reflectance, soiled fabric		
	%	%	%
(Unwashed fabric)	(38.5)		
0	51	51	52
5	53	53	54
10	55	56	57
	Soil removed		
	%	%	%
0	52	53	56
5	58	58	62
10	63	65	69

EFFECTS OF VARIOUS OPERATIONAL PRACTICES AND CONDITIONS

Length of Washing and Filtering Times

The effect of the length of filtrating time, 10, 20, or 30 minutes, following washing for varying periods of time, 0, 5, and 10 minutes, with 0.5% glyceryl monooleate in Stoddard solvent at a filtration flow rate of 40 changes per hour using the procedure of a detergency run followed by filtration (Part I), on the removal and redeposition of soil with cotton fabric is shown in Table 10.

Solvent Filtration Rate

To determine the optimum solvent flow rate through the filter, a series of tests was made using the procedure of a detergency run and filtration followed by filtration run in clean solvent (Part I), with the exception that no additive was put in the Stoddard solvent, and the filtration rinse with clean solvent was omitted. The results obtained, starting with standard soiled and unsoiled cotton fabric, are given in Table 11.

Multicycle Drycleaning

To determine the effects of further cycles of the detergency run—hand rinsing method, swatches were subjected to additional cycles using several different detergents at 0.5% concentration. The results are given in Table 5 of Part II.

Temperature of Bath

The temperature of the drycleaning bath in commercial practice may vary from zero to 40° C. It was, therefore, of interest to determine the effect of temperature on the soil removal and redeposition properties of several typical Stoddard solvent formulations. Four systems were used in the study: (1) Stoddard solvent alone and Stoddard solvent with each of the following additives, (2) a nonionic, glyceryl monooleate; (3) a mineral oil sulfonate,

Table 11.—The effect of filtration rate of solvent on the detergency efficiency of Stoddard solvent alone.

Test conditions			Fabric reflectance		
Wash time	Filter time	Solvent changes per hour	Unsoiled	Soiled	Soil removed
			%	%	%
(Unwashed fabric)			(87.0)	(38.5)	
0	20	20	62	40	6
0	20	30	67	41	16
0	20	40	70	41	16
0	20	60	70	41	14
0	20	80	73	42	21

Acto 700; and (4) a highly neutralized (95%) sodium oleate soap, soap D, both with and without added water. All the soiled and unsoiled fabric swatches were air-dried at 70° C. for 30 minutes before reflectance tests. The results obtained are given in Table 12.

Table 12.—Effect of temperature on soil removal and redeposition properties of several additives at 1.0% concentration in Stoddard solvent with and without added water.

Additive	H_2O liter of solvent	(Temperature (°C.) 0	15	25	40	60	80
	ml			*Reflectance, unsoiled fabric*			
		%	%	%	%	%	%
(Unwashed fabric)		(86.0)					
None	—	61	64	60	62	59	60
Glyceryl monooleate	0	83	83	83	81	77	72
Glyceryl monooleate	5	83	84	83	83	80	70
Acto 700	0	82	77	75	72	77	79
Acto 700	5	81	81	82	81	75	79
Soap D	0	82	81	79	75	72	Unreadable
Soap D	5	74	75	78	76	76	72
				Reflectance, soiled fabric			
		%	%	%	%	%	%
(Unwashed fabric)		(38.1)					
None	—	39	39	38	39	38	40
Glyceryl monooleate	0	54	52	53	54	52	51
Glyceryl monooleate	5	60	60	61	61	59	54
Acto 700	0	50	49	49	48	48	49
Acto 700	5	54	56	58	59	56	49
Soap D	0	49	51	52	51	53	Stiff & fuzzy
Soap D	5	51	53	57	55	53	50
				Soil removed			
		%	%	%	%	%	%
None	—	8	6	—2	5	14	8
Glyceryl monooleate	0	62	57	61	62	57	51
Glyceryl monooleate	5	75	75	77	76	73	62
Acto 700	0	51	49	49	46	46	48
Acto 700	5	61	68	71	73	66	48
Soap D	0	48	53	53	56	58	—
Soap D	5	56	59	68	65	61	50

Concentration of Drycleaning Additive

Texsol, F.B.C., Alrolene 70, Street's 886, and glyceryl monooleate were evaluated at several concentrations as detergent additives in Stoddard solvent with no added water in the system. The results are given in Table 13. Texsol,

Table 13.—Effect of additive concentration on soil removal and redeposition in Stoddard solvent without added water.

Additive	Additive concentration (%) 0.0	0.10	0.25	0.50	1.00	2.00	4.00	6.00
				Reflectance, unsoiled fabric				
	%	%	%	%	%	%	%	%
(Unwashed fabric)	(87.1)							
Texsol	62.2	65	67	71	76	80	80	80
F.B.C.	62.2	74	74	76	75	—	—	—
Alrolene 70	62.2	78	80	81	80	79	77	76
Street's 886	62.2	78	79	80	80	—	—	—
Glyceryl monooleate	62.2	78	81	82	82	82	82	—

Table 13.—Effect of additive concentration on soil removal and redeposition in Stoddard solvent without added water.

Additive	Additive concentration (%)							
	0.0	0.10	0.25	0.50	1.00	2.00	4.00	6.00
	Reflectance, soiled fabric							
	%	%	%	%	%	%	%	%
(Unwashed fabric)	(38.8)							
Texsol	37.8	39	42	46	51	51	50	51
F.B.C.	37.8	43	46	48	49			
Alrolene 70	37.8	50	53	54	55	58	58	59
Street's 886	37.8	49	50	50	50			
Glyceryl monooleate	37.8	51	54	55	56	53	53	
	Soil removed							
	%	%	%	%	%	%	%	%
Texsol	—5	1	16	33	52	51	49	51
F.B.C.	—5	24	35	44	47			
Alrolene 70	—5	49	58	60	63	70	69	72
Street's 886	—5	47	48	51	50			
Glyceryl monooleate	—5	53	62	64	66	58	59	

Table 14.—Effect of additive concentration and added water on soil removal and redeposition in Stoddard solvent.

Additives	Additive concentration	H_2O per liter of solvent (ml.)				
		0	1	2	3	4
		Reflectance, unsoiled fabric				
		%	%	%	%	%
(Unwashed fabric)	—	(86.5)				
None	—	62	62	61	61	60
Texsol	1	76	77	72	72	68
Do.	4	80	78	—	—	—
Alrolene 70	1	80	79	80	82	—
Do.	4	77	78	79	79	80
Glyceryl monooleate	1	82	82	82	83	83
Do.	4	82	82	83	83	—
		Reflectance, soiled fabric				
		%	%	%	%	%
(Unwashed fabric)	—	(38.7)				
None	—	38	39	40	40	39
Texsol	1	51	52	52	52	50
Do.	4	50	54	—	—	—
Alrolene 70	1	55	57	58	61	—
Do.	4	58	58	59	59	60
Glyceryl monooleate	1	56	54	55	56	57
Do.	4	53	54	56	57	—
		Soil removed				
		%	%	%	%	%
None	—	—5	3	11	8	3
Texsol	1	52	56	56	56	51
Do.	4	49	61	—	—	—
Alrolene 70	1	63	68	70	77	—
Do.	4	69	71	73	72	75
Glyceryl monooleate	1	66	62	65	67	69
Do.	4	59	63	62	68	—

Table 15.—Effect of additive concentration on percent soil removed[1]

Additive	Concentration	Febric reflectance		Soil removed
		Unsoiled	Soiled	
	%	%	%	%
(Unwashed fabric)		(87.2)	(38.0)	
Alrolene 70	0.5	82	54	62
	1	81	55	65
	2	81	55	65
	4	80	56	67
Hydrol	0.5	78	51	54
	1	79	52	57
	2	78	52	57
	4	78	52	57
Glyceryl monooleate	0.5	81	52	58
	1	82	53	60
	2	83	53	60
	4	83	54	62
Acto	0.5	82	50	53
	1	82	51	54
	2	82	49	48
	4	82	50	51
Compound K	0.5	82	54	62
	1	82	53	60
	2	82	52	58
	4	83	52	27

[1] One milliliter of water per liter of solvent added after drying the solvent with eight pieces of bone dry unsoiled test fabric.

Alrolene 70, and Glyceryl monooleate were evaluated at 1 and 4 percent concentrations in Stoddard solvent with varying amounts of added water. The results are given in Table 14. Alrolene 70, Hydrol, glyceryl monooleate, Acto, and compound K were evaluated at several concentrations in Stoddard solvent which had been dried by agitating 8 bone-dry swatches in the bath for 10 minutes before each detergency run then adding exactly 1 milliliter of water per liter of solvent. The results are given in Table 15. Other work with additive concentrations is reported in Table 4 of Part II.

Moisture Content of Drycleaning Bath

Single-cycle drycleaning tests.—In this series of tests a 10-minute wash time was used followed by hand rinsing the test swatches in clean solvent. After centrifuging, the swatches were air-dried and reflectances determined with the photovolt reflectometer. Aerosol OT, Alrolene 70, and glyceryl monooleate S-1097 were used at 1 percent concentration. Water was added in amounts ranging from 1 to 80 milliliters per liter of Stoddard solvent. The results obtained are given in Table 16. Results of other experiments conducted in a similar manner and varying the moisture content of the drycleaning bath are reported in Tables 6, 8, 9, 12, and 14 of this Part and in Table 4 of Part II.

Table 16.—Effect of added water on the detergency efficiencies of various additives in single cycle dry cleaning tests in Stoddard solvent[1]

Additive	H_2O per liter of solvent (ml.)											
	0	1	2	3	4	5	10	15	20	25	40	80
	Reflectance, unsoiled fabric											
	%	%	%	%	%	%	%	%	%	%	%	%
(Unwashed fabric)	(86.7)											
None	62	62	61	61	60							
Aerosol OT	73	72	72	74	75	75	80	81	81	82	82	77
Alrolene 70	82	79	80	81	82	83	84	84	83	83	84	83
Glyceryl monooleate	82	82	82	83	83	83	82	82	82	—	—	—
	Reflectance, soiled fabric											
	%	%	%	%	%	%	%	%	%	%	%	%
(Unwashed fabric)	(38.6)											
None	38	39	40	40	39							
Aerosol OT	46	45	47	49	51	53	59	62	63	63	62	55
Alrolene 70	59	57	58	60	61	63	62	62	62	62	63	60
Glyceryl monooleate	53	54	56	57	60	60	60	60	58	—	—	—

Table 16.—Effect of added water on the detergency efficiencies of various additives in single cycle dry cleaning tests in Stoddard solvent [1]

Additive	H_2O per liter of solvent (ml.)											
	0	1	2	3	4	5	10	15	20	25	40	80
	Soil removed											
	%	%	%	%	%	%	%	%	%	%	%	%
None	4	3	11	8	3							
Aerosol OT	33	35	41	48	55	59	73	78	80	80	78	63
Alrolene 70	61	67	70	74	76	79	77	78	77	78	78	75
Glyceryl monooleate	58	61	65	67	69	74	74	74	69	—	—	—

[1] All additives used at 1% concentration.

Multi-cycle drycleaning tests.—Multicycle drycleaning tests were made with many of the same additives used in single-cycle drycleaning tests in Stoddard solvent. The fabric swatches were not resoiled between drycleanings. Four soiled and four unsoiled cotton fabric swatches were given a 10-minute run in the Terg-O-Tometer at 150 cycles per minute, rinsed by hand in clean solvent, centrifuged, dried, and the reflectance determined with the photovolt reflectometer after each drycleaning cycle. The results obtained using Aerosol OT, Alrolene 70, and glyceryl monooleate at 0.5% with and without 5 milliliters of water per liter of solvent are given in Table 17.

Table 17.—Effect of multi-cycle dry cleaning without resoiling on detergency of various additives in the presence and absence of added water in Stoddard solvent [1]

Additives	H_2O per liter solvent	Cycle number							
		1	2	3	4	5	6	7	8
	(ml.)								
		Reflectance, unsoiled fabric							
		%	%	%	%	%	%	%	%
Unwashed fabric)	—	(86.4)							
None	0	61	58	56	56	55	55	54	54
Aerosol OT	0	73	73	74	73	73	73	73	73
	5	76	78	79	78	78	78	78	78
Alrolene 70	0	82	82	82	82	81	82	82	80
	5	83	84	84	85	85	84	84	84
Glyceryl monooleate	0	82	82	83	83	82	82	82	81
	5	82	84	84	84	85	84	84	84
		Reflectance, soiled fabric							
		%	%	%	%	%	%	%	%
(Unwashed fabric)		(38.5)							
None	0	37	38	38	38	38	37	38	38
Aerosol OT	0	46	47	48	48	48	48	49	49
	5	56	59	60	61	61	62	62	62
Alrolene 70	0	54	58	60	61	62	62	63	63
	5	62	67	68	69	70	71	72	72
Glyceryl monooleate	0	53	55	57	58	58	59	59	60
	5	59	64	65	67	67	67	68	69
		Soil removed							
		%	%	%	%	%	%	%	%
None	0	—4	—6	—6	—5	—4	—9	—3	—2
Aerosol OT	0	33	38	43	43	44	44	46	48
	5	66	72	75	76	77	78	78	78
Alrolene 70	0	61	70	74	76	77	79	80	79
	5	77	85	87	88	89	90	91	91
Glyceryl monooleate	0	58	64	68	70	71	72	73	74
	5	73	81	83	85	86	85	87	88

[1] Additives used at 0.5% concentration.

Varying moisture by preconditioning fabric to different moisture regain levels.—A series of desized, kiered, and bleached cotton print cloth (80 x 80) samples were prepared, each weighing about 2.2 grams. The samples were conditioned under the prevailing conditions of the laboratory and the moisture content of four selected samples determined, using the Seaman, McComas, and Allen (37) modification of the Karl Fischer method. The weight of each sample was then corrected to bone-dry weight, using the average moisture content found for the four analyzed samples. The samples of known dry weight were preconditioned to different moisture regain levels before drycleaning by a single cycle of the detergency run-hand rinsing method of Part I.

The range of moisture regains in the fabric were obtained at the lower percentages by conditioning in an atmosphere of known relative humidity and at the higher percentages by wetting out in water and allowing to dry to the desired pickup. In the determination of the moisture relationship between the fabric and solvent system, a sample of the fabric of known dry weight was introduced into the tared separatory funnel and the increase in weight noted. The regain of the fabric was then calculated from the dry weight of the sample and conditioned weight data.

For the moisture evaluation a large supply of Stoddard solvent, commercial standard CS 3-40, containing a known amount of Aerosol-OT and water, was prepared and stored in a glass-stoppered container so arranged that exactly 25-milliliter aliquots could be withdrawn and delivered to a separatory funnel having a drawn-out tip without exposure to the atmosphere. The separatory funnel had a sufficiently large ground-glass opening to allow easily the introduction of the fabric sample into the funnel and was of 50-milliliter capacity.

To the tared funnel containing the fabric of known moisture content was added 25 milliliters of the standard solution of Stoddard solvent containing Aerosol-OT and water and the exact weight of solution obtained by reweighing. The funnel was then vigorously shaken for exactly 10 minutes and again weighed to compensate for any evaporation losses. A portion of the solvent was then drawn off directly into a stoppered flask containing a standard pyridine-methyl alcohol-SO_2 solution (solution A) and the water titrated directly with standard iodine-methanol solution (solution B) to a visual end point. The weight of reacted solvent delivered for titration was determined by the difference in the weight of the funnel before and after sampling.

The Karl Fischer reagent was prepared in the laboratory as two separate solutions in order to minimize deterioration of the reagent. In this case, rather than adding an excess of reagent and back titrating with a standard, the water was titrated directly. If the aliquot portion of the pyridine-MeOH-SO_2 solution (solution A) is pretitrated with the standard iodine-solution (solution B) before introducing the water, the water equivalent may be determined and applied in the determination. Sodium tartrate dihydrate crystals were the primary standard used to determine the water equivalence of solution B. The ratio of fabric weight to solvent weight varied between 1:9.0 and 1:9.5 in the test series. The moisture regains before and after drycleaning with Stoddard solvent using 1% Aerosol-OT and 0.85% water are given in Table 18 for a graded series of original moisture regains.

Table 18.—Effect of the initial moisture regain of cotton fabric on the equilibrium moisture distribution in the system: Stoddard solvent (containing 1% Aerosol-OT and 0.85% water)—cotton fabric.

Cotton fabric moisture regain, %			H_2O in solvent at equilibrium, %
Initial	Final	Change	
0.31	6.65	+6.34	0.115
3.74	9.76	+6.02	.167
5.40	11.13	+5.73	.206
6.68	12.05	+5.33	.234
6.81	12.33	+5.41	.225
9.28	14.05	+4.77	.308
14.76	18.83	+4.07	.385
22.15	24.68	+2.53	.563
23.35	25.22	+1.87	.646
26.06	26.97	+0.91	.833
40.48	32.14	—8.34	1.863

In another series of tests three types of drycleaning additives were used; namely; a nonionic, glyceryl monooleate; an ionic, dioctyl ester of sodium sulfosuccinic acid, Aerosol-OT;

and an oleic acid soap, 70% neutralized with ethanolamine, soap K. The fabric test swatches were conditioned at the various relative humidities listed in Tables 19, A, B, and C, and then placed in the Stoddard solvent bath containing 1 percent of the various additives. Any water carried into the bath by the additive was removed by first putting eight bone dry unsoiled fabric swatches in the system and agitating for 10 minutes. Known amounts of water were then added. The test swatches introduced into the system consisted of four unsoiled and four soiled. After agitating in the closed system for 10 minutes, the swatches were removed and, after a hand rinse in clean solvent, centrifuged and dried. The reflectances were determined using a Photovolt Reflectometer in th usual manner. The results obtained are summarized in Tables 19, A, B, and C.

Table 19A.—Effect of preconditioning cotton print cloth at various relative humidities using various additives and varying amounts of water on percent reflectance of unsoiled fabrics [1].

RH of conditioning	Ml. added water				
	0	1	3	5	Av.
	Glyceryl monooleate				
Bone dry	83	82	81	81	81.8
31%	83	82	82	83	82.5
51%	83	82	83	83	82.8
71%	83	82	83	84	83.0
59%	82	82	83	83	82.5
88%	82	80	82	82	81.5
100%	83	83	83	83	83.0
Av.	82.7	81.9	82.5	82.7	
	Aerosol-OT				
Bone dry	77	76	75	77	76.2
31%	79	78	78	77	78.0
51%	78	78	78	77	77.8
71%	78	78	78	77	77.8
79%	78	78	78	78	78.0
88%	76	76	77	77	76.5
100%	79	78	77	77	77.8
Av.	77.9	77.5	77.3	77.2	
	Soap K				
Bone dry	81	80	80	82	80.8
31%	82	81	82	83	82.0
51%	82	82	83	83	82.5
71%	81	81	83	83	82.0
79%	81	80	83	83	81.8
88%	80	80	84	83	81.8
100%	80	80	82	83	81.2
Av.	81.0	80.6	82.5	82.9	

[1] All additives used at 1.0 percent concentration. Indicated amounts of water added to solvent after first drying with eight pieces of bone-dry unsoiled test fabric.

Table 19B.—Effect of preconditioning cotton print cloth at various relative humidities using various additives and varying amounts of water on percent reflectance of soiled fabric [1].

RH of conditioning	Ml. added water				
	0	1	3	5	Av.
	Glyceryl monooleate				
Bone dry	50	53	55	58	54.0
31%	51	53	55	57	54.0
51%	50	53	56	57	54.0
71%	52	54	56	58	55.0
79%	51	54	56	58	54.8
88%	52	52	56	58	54.5
100%	52	54	57	58	55.2
Av.	51.2	53.3	55.9	57.7	
	Aerosol-OT				
Bone dry	46	47	49	52	48.5
31%	47	47	51	53	49.5
51%	47	48	50	53	49.5
71%	47	48	51	53	49.8
79%	47	48	50	54	49.8
88%	46	46	51	54	49.2
100%	47	48	52	55	50.5
Av.	46.7	47.4	50.6	53.4	
	Soap K				
Bone dry	50	52	55	59	54.0
31%	51	53	57	59	55.0
51%	51	54	56	58	54.8
71%	52	54	57	59	55.5
79%	52	53	56	58	54.8
88%	52	54	56	58	55.0
100%	52	54	56	57	54.8
Av.	51.4	53.4	56.2	58.3	

[1] All additives used at 1.0 percent concentration. Indicated amounts of water added to solvent after first drying with eight pieces of bone-dry unsoiled test fabric.

Table 19C.—Effect of preconditioning cotton print cloth at various relative humiditiees using various additives and varying amounts of water on percent soil removed [1].

RH of conditioning	Ml. added water				
	0	1	3	5	Av.
	Glyceryl monooleate				
Bone dry	48	57	63	70	59.5
31%	54	58	64	69	61.2
51%	51	58	66	68	60.8
71%	54	60	66	70	62.5
79%	51	60	67	71	62.2
88%	55	55	67	70	61.8
100%	57	64	67	70	64.5
Av.	52.9	58.9	65.7	69.7	
	Aerosol-OT				
Bone dry	34	36	44	56	42.5
31%	36	39	57	57	47.2
51%	37	41	49	58	46.2
71%	37	40	50	59	46.5
79%	38	39	50	59	46.5
88%	33	35	50	59	44.2
100%	38	43	53	61	48.8
Av.	36.2	39.0	50.4	58.4	
	Soap K				
Bone dry	48	54	62	70	58.5
31%	51	56	67	72	61.5
51%	50	60	65	70	61.2
71%	53	60	67	72	63.0
79%	56	57	66	70	62.2
88%	53	59	66	70	62.0
100%	55	59	64	66	61.0
Av.	52.3	57.9	65.3	70.0	

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[1] All additives used at 1.0 percent concentration. Indicated amounts of water added to solvent after first drying with eight pieces of bone-dry unsoiled test fabric.

DISCUSSION

CONVENTIONAL DRYCLEANING SOLVENTS

At the present time about 80% of the drycleaning industry uses Stoddard solvent as a drycleaning medium; but the use of chlorinated hydrocarbons, particularly perchloroethylene (Perk), is increasing. It was accordingly of interest to determine the relative effectiveness of these two primary drycleaning solvents in the presence and absence of additives and water on soil removal and redeposition on cotton fabrics. It will be noted, (Table 6), that Stoddard solvent and perchloroethylene are about equally effective in soil removal in the absence of an additive, though neither is very efficient. Redeposition is greater for perchloroethylene than for Stoddard solvent. Percent soil removed is increased by using either glyceryl monooleate or Calcharge as an additive. Again soil removal is about the same for perchloroethylene as for Stoddard solvent, though redeposition is much greater with perchloroethylene than with Stoddard solvent. Cleaning was not noticeably affected by adding 0.5 ml. of water per liter of solvent, though redeposition was increased, and increased more in perchloroethylene than in Stoddard solvent. Though the generalities above would indicate that Stoddard solvent is a better drycleaning medium than perchloroethylene it is to be noticed that perchloroethylene with glyceryl monooleate, and no added water, is as efficient in soil removal as the best combination of Stoddard solvent, with nearly as little redeposition. Accordingly this points up the fact that care must be exercised to specify always the solvent used and moisture content of the system as well as the drycleaning additive when discussing drycleaning practices.

OTHER SOLVENTS FOR DRYCLEANING

Fifteen selected organic solvents in addition to Stoddard solvent and perchloroethylene have been investigated in drycleaning systems for cotton. Drycleaning tests were run under three conditions for each of the solvents, namely, no additive, 1% glyceryl monooleate, and 1% glyceryl monooleate plus 5 milliliters of water per liter of solvent, Table 8. Glyceryl monooleate was chosen as the additive because of its nonionic nature and because of its high detergency efficiency in Stoddard solvent.

When no additive was used, it should be noted that practically all of the solvents investigated were better detergents than Stoddard solvent and perchloroethylene, Table 8. In no case did the addition of glyceryl monooleate alone or in the presence of water increase the detergency of the other solvents used as much as was the case with Stoddard solvent and perchloroethylene. In general, it seems that the solvents, such as ethyl acetoacetate, dichloroethyl ether, and cellosolve solvent, which have the highest detergency properties alone, respond the least to the addition of the drycleaning additive in the presence or absence of added water. In fact, detergent efficiency in these systems is less than zero. On the other hand, solvents showing poor detergency alone repond to the addition of a surfactant and water, as in the cases of tetrahydronapthalene, alpha pinene, n-butyl ether, and di-isobutyl ketone. In no case, however, was the detergency efficiency of the surfactant as great as with Stoddard solvent and perchloroethylene.

The fact that glyceryl monooleate does not increase the detergent properties of solvents containing functional groups while it is effective with most of the solvents not containing functional groups is of interest, since the polarity of the solvent molecule must play an important part in detergency. The free hydroxyl groups in glyceryl monooleate have no opportunity to aid the detergent properties of some of the solvents, probably because of the influence of the polar functional groups of the solvent. The failure of glyceryl monooleate to show high detergent efficiency in most of these unconventional drycleaning solvents should not be interpreted to mean that further research would be useless, since it is possible that an additive could be found that would increase the already high efficiency of these solvents to a point far beyond any presently realized with conventional drycleaning solvents.

In the drycleaning tests made with mixtures of solvents nine parts of Stoddard solvent or perchloroethylene were used with one part of ethyl acetoacetate, cellosolve solvent, or dichloroethyl ether, Table 9. These mixtures were used alone and with 1 percent of guanidine oleate, Street's 886, and glyceryl monooleate with and without 0.5 milliliter of water per liter of solvent. The high detergency properties of each of the new organic solvents when used alone were lost when mixed with either Stoddard solvent or perchloroethylene in the ratio used in these tests, although the presence of dichloroethyl ether did not appreciably effect the detergency efficiencies of the additives in the conventional drycleaning solvents. On the other hand, the ester ethyl acetoacetate, and the glycol ether, cellosolve solvent, when added to either Stoddard solvent or perchloroethylene, retarded the detergent efficiencies of the additives in all cases. The addition of water to these systems had the effect in general of reducing the detergency efficiency except when dichloroethyl ether was added to Stoddard solvent and/or perchloroethylene.

EFFECTS OF VARIOUS DRYCLEANING ADDITIVES

Results with various additives are reported in Tables 4 and 5 of Part II, and in Tables 6, 9, 12, 13, 14, 15, 16, 17, and 19, A, B, and C of this part.

Some of the better additives from the viewpoints of both increased soil removal and decreased soil redeposition in clean fabric are Alrolene 70, Acto 450, Acto 700, and glyceryl monooleate. These additives consistently gave soil removal values over 70 percent for one 10-minute cycle of washing at prevailing temperatures with 1 percent additive and not over 5 milliliters of water per liter of Stoddard solvent. The percent soil removed can be made to approach 80 percent by using more washing and rinsing cycles. The light reflectance values of unsoiled fabric washed with these additives in the presence of soiled fabric were consistently 80 percent or better when the reflectance of the original clean fabric was 86 to 87 percent.

EFFECTS OF VARIOUS OPERATIONAL PRACTICES

From Table 10 it is evident that increasing either washing or filtering time increased soil removal. The 5-minute differences in length of washing time created larger differences in reflectance and soil removal than the 10-minute differences in filtering time. Fabrics washed and filtered for a total of 20 or 30 minutes were cleaner than those filtered only for the same lengths of time, compare no washing but 20 and 30 minutes filtering with 10 minute washing plus 10 and 20 minute filtering, respectively.

Redeposition was not affected by length of washing and filtering times within the range of 0 to 10 minutes washing time and 10 to 20 minutes filtering time.

Another way in which soil loosened by detergent action can be removed from the vicinity of the fabric is to increase the solvent flow rate during the filtration cycle, Table 11. Although this test was performed in the absence of a drycleaning additive, it does give an indication that both soil removal and prevention of soil redeposition can be increased by increasing the solvent flow rate during filtration.

The amount of drycleaning action can be increased by returning the fabric for further cleaning cycles without any additional soiling between cycles. The results of such multicycle drycleaning are reported in Table 5 of Part II. The greatest portion of soil removal occurs during the first cycle though there is some further removal with further drycleaning cycles. The amount of redeposited soil did not seem to change with further washing cycles.

The results of varying the temperature of the drycleaning bath are reported in Table 12. Temperature did not affect the soil removed by Stoddard solvent alone. Soil removal of the three additive systems, glyceryl monooleate, Acto 700, and soap D, both with and without added moisture, was decreased at temperatures of 60° and 80° C. Maximum soil removal with each of the additives was obtained in the range of temperatures commonly prevailing in commercial operations, 10° to 40° C.

Data on concentration of additive, Tables 13, 14, and 15 of this Part III and 4 of Part II indicate in general no advantages from using additives at concentrations in excess of one-half to one percent. Exceptions to this are Span 80 and Naccolene.

MOISTURE CONTENT OF DRYCLEANING BATH

The results of the single cycle tests with varying quantities of water, (Table 14), indicate that adding water to Stoddard solvent alone had little effect on either soil removal or redeposition. However, adding Aerosol-OT, Alrolene 70, or glyceryl monooleate increased soil removal and decreased soil redeposition. Adding water to each of the three systems increased soil removal and decreased soil redeposition still further. The maximum response was reached with less water for Alrolene 70 and glyceryl monooleate than for Aerosol-OT. The data indicate that Aerosol-OT, a dioctyl ester of sodium sulfosuccinic acid, required more than 10 ml. of water per liter of solvent for maximum effects while Alrolene 70 and glyceryl monooleate gave maximum effects with 5 ml. or less. Five ml. of water per liter of solvent is regarded as a practical amount of water. Other tests, Tables 8, 9, 12, 14, 17, and 19 (A, B, C) of this Part, and Table 4 of Part II also indicate that small quantities of additional water improve the detergency efficiency of many surfactant materials.

In the multi-cycle drycleaning tests with Aerosol-OT, Alrolene 70, and glyceryl monooleate in concentrations of 0.5% in the presence and absence of added water, (Table 17), the beneficial effects of additives and of adding water to the system are again shown. As fabric was subjected to successive drycleaning cycles in Stoddard solvent without additive, soil removal was not improved and redeposition was increased. In the presence of additives, however, increased number of cycles brought increased soil removal and decreased redeposition, though the greatest response was from the first cycle.

Redeposition was less with Alrolene 70 and glyceryl monooleate than with Aerosol-OT and less for every additive with water than without. Soil removal was greater for each additive in the presence of added water than in the absence and was more for Alrolene 70 than for glyceryl monooleate which was greater than for Aerosol-OT.

It seems reasonable that the amount of moisture in the fabric when placed in the bath can affect both moisture content of the bath and detergency efficiency. Bird (5) found that there was an equilibrium between the moisture in the drycleaning soap bath and the moisture in wool. When wool contained below 22% moisture, it would pick up moisture from the solvent-soap-water system, while above that point moisture was removed from the fabric.

Brown (6) and later Bird (4) have shown that, when wool is predried before drycleaning, the detergency is not good. It was also found that, if this same fabric was allowed to regain moisture before detergency treatment, the soil was more easily removed. It has also been shown (16, 19, 20, 21, 24) that, where no soap was used, the minimum redeposition of soil was found when regenerated rayon was preconditioned in an atmosphere of 40 to 60% relative humidity. This would indicate that the moisture regain of rayon fabric should be between 8.8% and 12.2% to obtain the best detergency. From these observations it is surmised that the detergency of cotton fabric in nonaqueous solvents will also be influenced by the moisture content.

Because the partially neutralized fatty acid, as well as the alcohol, can influence the equilibrium due to the absorption of one or both of these materials from the system by the fabric, and because any slight fluctuation of conditions could cause complications, it was decided to eliminate these factors and use a single solubilizing agent, Aerosol-OT, in the experiment to determine the relationship between regain of fabric and moisture content of drycleaning bath. The drycleaning soap formula used in the studies by Bird contained an alcohol, such as methyl alcohol or cyclohexanol, which acts as a solubilizing agent for water in the system. The use of alcohols as carriers for water in the presence of partially neutralized, 70 to 90%, fatty acids has been common practice in proprietary formulations for many years. The use of a 1:9-9.5 cotton cloth to solvent ratio by weight is in line with commercial practice.

The results on moisture gain or loss in the drycleaning bath as affected by moisture regain of the fabric are reported in Table 18 where it may be noted that the equilibrium point for initial and final fabric moisture regain, where the cotton fabric neither gives up nor takes up water, is between 27 and 28%. This conclusion is further substantiated by data showing the amount of water in the solvent at equilibrium. It will be noted also that the moisture regain changes are positive and large at low initial regains, decreasing in magnitude as initial regain approaches 27% and becoming negative thereafter. Thus, the fabric acquires moisture from the solvent system at lower regain values but gives up moisture to the solvent at higher regain values when the solubilizing agent, Aerosol-OT, is present. This finding should be helpful in understanding the role of detergents in drycleaning of cotton.

For years conditioning of fabrics at a controlled humidity prior to drycleaning has been suggested, but it has become standard practice in very few plants. In view of the finding that soil removal from cotton fabric is aided by the introduction of water into the detergent bath, and that cotton fabric can either gain water from, or lose water to, the bath, it was felt necessary to determine if preconditioning of fabric had a marked influence on soil removal. The data presented in Tables 19 A, B, and C indicate that the initial moisture content of the fabric prior to drycleaning has far less influence on the drycleaning detergency of cotton fabric than the introduction of moisture into the detergent bath.

The data in Table 19 A, indicate that the percent reflectance of unsoiled fabric swatches washed to measure redeposition varies with the additive used. Redeposition is much less for Aerosol-OT than for glyceryl monooleate and soap K. With all three materials there is some evidence that redeposition on fabric conditioned to bone dryness is greater than on fabric conditioned with some moisture in the air. Redeposit with soap K seems to be reduced at higher levels of added water.

Table 19 C, indicates that glyceryl monooleate and soap K remove considerably more soil than Aerosol-OT at all levels of conditioning and added water. With no water added, the detergency of glyceryl monooleate and soap K is increased by conditioning the fabric in atmosphere of higher relative humidity. However, the addition of 5 milliliters of water per liter of solvent is sufficient with these two solvents to mask the differences due to preconditioning. Thus, preconditioning could be important if water could not be added to the system, but in practice enough water can be added to attain maximum detergency regardless of the moisture regain of the fabric. Aerosol-OT did not exhibit such differential behavior nearly so markedly, if at all.

A possible explanation for free water in the bath increasing detergent efficiency of the systems studied, more than the bound water in the fabric, may be found in the electrical charges on soil particles and fibers. When the soiled fabric is preconditioned at high relative humidities, the fabric may take up more moisture than the soil and assume charges quite different in magnitude from that of soil when introduced into a nonaqueous system. When water is introduced into the drycleaning bath, the soil and fabric may both assume nearly equal charges; and soil removal is increased as well as redeposition of soil decreased. The possibility of surface swelling of the fibers that may release a greater amount of soil should also be considered.

CONCLUSIONS

(1) Where fire hazards are involved, perchloroethylene can be used in place of Stoddard solvent, since, with the proper selection of additives, there is little difference in detergency efficiency. However, within the limitations of the present investigation, there is a tendency for soil to be redeposited from perchloroethylene to a greater extent than from Stoddard solvent with some additives.

(2) Fifteen organic solvents, selected because of the functional groups present in their structure, were evaluated as drycleaning solvents for cotton fabric. None are as efficient as the conventional drycleaning solvents, Stoddard solvent and perchloroethylene when used correctly. Possible effects on fastness of dyestuff and on fabric properties were not determined.

(3) Ethyl acetoacetate, cellosolve solvent, and dichloroethyl ether were found to have high detergency properties alone but decreased effectiveness in the presence of a drycleaning additive and water.

(4) The addition of a surfactant to either Stoddard solvent or perchloroethylene resulted in higher detergency efficiencies than were obtained with any of the 15 other organic solvents investigated.

(5) Mixtures of ethyl acetoacetate and cellosolve solvent with Stoddard solvent and perchloroethylene (1:9) used with and without drycleaning additives and with and without added water were less efficient than the undiluted conventional drycleaning solvents.

(6) Mixtures of dichloroethyl ether with Stoddard solvent and perchloroethylene (1:9) had about the same detergency efficiencies as the undiluted conventional drycleaning solvents when used with certain drycleaning additives. Addition of water to these systems increased drycleaning efficiencies.

(7) The use of drycleaning surfactants in drycleaning solvents is essential to high soil removal and prevention of soil redeposit with cotton fabrics in both single- and multi-cycle drycleaning procedures.

(8) The detergent power of Stoddard solvent is greatly increased by the appropriate detergent additives. Among the additives tested, Alrolene 70, Acto 450, Acto 700, glyceryl monooleate, and ethanolamine- and sodium-oleate give the greatest percentage soil removal.

(9) Tween 80, and to a lesser extent Tween 60, show highly anomalous behavior. The specific absorbence of the soil is greatly increased, and redeposit is very high. While this is most undesirable in drycleaning, these materials may be of interest as filter aids in such applications as desludging lubricating oils.

(10) Soil removed from drycleaned cotton fabric is increased by longer washing, longer filtering, higher solvent filtration rates, and by additional drycleaning cycles.

(11) At temperatures of 40° C. and lower, variation in temperature has little effect on the drycleaning efficiency of most additives; but at higher temperatures detergency efficiency tends to decrease with soil redeposition becoming prominent.

(12) The use of high concentrations of detergents in Stoddard solvent does not seem to be greatly beneficial in the drycleaning of cotton fabric. Only small increases in detergent efficiency are produced by detergent additions of over 0.5% of total solvent.

(13) The use of small quantities of water (1 to 10 milliliters per liter of solvent) gives an appreciable increase in the efficiency of some detergents. Larger quantities do not seem to confer great additional improvement. The optimum amount may vary for different additives.

(14) In multi-cycle drycleanings, the greatest portion of the soil removed from soiled cotton fabric, and the greatest redeposition, occurs during the first cycle. After the first

cycle, with most additives, soil removal continues with little or no further redeposition of soil. The presence of water in controlled amounts and within definite limits increases the rate of soil removal and minimizes soil redeposition when additives are present in the drycleaning bath for the detergent systems studied.

(15) The cotton fabric moisture regain at which water is neither gained nor lost to the drycleaning solvent lies between 25 and 30% depending upon the type and concentration of additive present. Below this point a practically linear relation exists between the moisture contents of the solvent and the cotton fabric.

(16) Using drycleaning systems with no free water the percent soil removed is greater for fabric preconditioned to higher regain values. However, free water added to the system obliterates differences due to fabric moisture so that in practice there would seem to be no merit in the statement that preconditioning fabric to the proper regain can improve detergency.

PART IV — PRELIMINARY INVESTIGATIONS IN THE DRYCLEANING OF COTTON FABRIC SOILED WITH WATER SOLUBLE SOIL

by

Jack Compton and Leo R. Hubbard

INTRODUCTION

EXPERIMENTAL

- PREPARATION OF SALT- AND SUGAR-CONTAMINATED COTTON FABRIC
- DRYCLEANING PROCEDURE
- SALT DETERMINATION IN CONTAMINATED COTTON FABRIC
- SUGAR DETERMINATION IN CONTAMINATED COTTON FABRIC

DISCUSSION

CONCLUSIONS

INTRODUCTION

In domestic and commercial drycleaning, if drycleaned clothes look clean and smell clean, they are regarded as being clean. This criterion is not always reliable, however, since many soils acquired in service are colorless or nearly so and are detected only by a change in hand of the fabric and in some cases by an attending sweaty or musty odor. The worst offenders in this regard are sugar and salt soils acquired in service.

With the current trend toward the addition of water to the drycleaning solvent system to increase detergency efficiency and minimize hand spotting, the transfer of water-soluble soils from soiled to unsoiled clothes during drycleaning becomes more likely. Special attention must be given to this problem by the drycleaner.

Since this problem is of increasing importance to the drycleaning industry, it was of interest to determine some of the factors responsible for the transfer of water-soluble soils and how these may be controlled in the drycleaning of cotton fabric.

EXPERIMENTAL

PREPARATION OF SALT- AND SUGAR-CONTAMINATED COTTON FABRIC

Desized, kiered, and bleached cotton print cloth (80 x 80) was cut into 6 x 6-inch swatches and contaminated with either 100 milligrams of salt or sugar (sucrose) by pipetting 1 milliliter of a 10% solution of these substances in water separately over the swatches and then allowing these to air-dry. This procedure simulated the spotting of fabrics with soft drinks and other sugar- and salt-containing liquids and foods during wear.

DRYCLEANING PROCEDURE

One dry salt- or sugar-contaminated and seven dry uncontaminated desized, kiered, and bleached print cloth (80 x 80) swatches were given a 10-minute soap run with the Terg-O-Tometer component of the laboratory drycleaning unit operating at 150 cycles per minute, followed by a 20-minute filtration run, detergency run followed by filtration as outlined in Part I. Drycleaning tests were made in Stoddard solvent at 0.5% and 4.0% additive concentrations in the presence of 1, 3, and 5 milliliters of added water per liter of solvent and in the absence of water. Glyceryl monooleate S-1097 and the proprietary drycleaning soap, Street's 886, were used as additives in these tests. Aerosol-OT was also used as an additive in the salt contamination studies.

After the drycleaning run, the eight fabric swatches were removed from the drycleaning bath and, after extraction, allowed to air-dry. The contaminated swatch and one unsoiled swatch from each run were analyzed to determine the amount of salt or sugar removed from the soiled swatch and transferred to the unsoiled swatches.

Large swatches of white cotton fabric were drycleaned ten times with regular loads of drycleaning, after which they were analyzed for the presence of salt.

SALT DETERMINATION IN CONTAMINATED COTTON FABRIC

Distilled water (100 milliliters) containing 2 milliliters of concentrated nitric acid was added to the fabric sample in a 500-milliliter flask; then an excess of approximately 0.1N silver nitrate solution was added to the flask and swirled until the silver chloride precipitate had coagulated, and then five drops of saturated ferrous ammonium sulfate were added. The excess silver nitrate was titrated with 0.1 N potassium thiocyanate solution to the appearance of the ferric-thiocyanate complex color. The results are expressed in percent. The chlorides in the unwashed sample, calculated as NaC1, are taken as 100%. The results obtained with salt contaminated swatches are given in Tables 20, 21, and 22.

Table 20.—Salt transfer from contaminated to uncontaminated cotton fabric during drycleaning using 0.5% and 4.0% glyceryl monooleate S-1097 in Stoddard solvent containing various amounts of added water.

Additive conc., (%)	Water added ml./1	Salt after dry cleaning, %		Salt in bath, %	Ratio $\frac{F_R}{F_T}$
		F_R, Fabric residual salt	F_T, Fabric transferred salt		
—	—	100	0.0	0.0	——
0.5	0	96	0.0	4.0	> 96
.5	1	90	4.0	6.0	22.5
.5	3	65	32.0	3.0	2.0
.5	5	34	44.0	22.0	.8
4.0	0	70	10.0	20.0	7.0
4.0	1	70	14.0	16.0	5.0
4.0	3	51.5	33.0	15.5	1.6
4.0	5	39.0	33.0	28.0	1.2

Table 21.—Salt transfer from contaminated to uncontaminated cotton fabric during drycleaning using 0.5% and 4.0% Street's 886 in Stoddard solvent containing various amounts of added water.

Additive conc. (%)	Water added ml./1.	Salt after dry cleaning, %		Salt in bath, %	Ratio $\frac{F_R}{F_T}$
		F_R, Fabric residual salt	F_T, Fabric transferred salt		
—	—	100	0.0	0.0	——
0.5	0	95.5	0.0	4.5	> 95
.5	1	90.2	4.1	5.7	22.0
.5	3	64.7	32.1	3.2	2.0
.5	5	34.0	44.0	22.0	.8
4.0	0	64.0	10.0	26.0	6.4
4.0	1	51.0	14.0	35.0	3.6
4.0	3	31.5	30.0	38.5	1.5
4.0	5	28.7	38.0	33.2	.8

Table 22.—Salt transfer from contaminated to uncontaminated cotton fabric during drycleaning using 0.5% and 4.0% Aerosol-OT in Stoddard solvent containing various amounts of added water.

Additive conc. (%)	Water added ml./1.	Salt after dry cleaning, %		Salt in bath, %	Ratio $\frac{F_R}{F_T}$
		F_R, Fabric residual salt	F_T, Fabric transferred salt		
—	—	100.0	0.0	0.0	——
0.5	0	109.0	8.6	.0	12.7
.5	1	96.0	13.0	.0	7.4
.5	3	85.0	.0	15.0	> 85
.5	5	36.0	73.0	.0	.5
4.0	0	115.0	.0	0.0	> 115
4.0	1	109.0	.0	.0	> 109
4.0	3	82.0	13.0	5.0	6.3
4.0	5	32.5	63.0	4.5	.5

Calculations: (KCNS = 0.1 N)

(1) (milliliters KCNS solution for blank — milliliters KCNS solution for sample) × N × 58.5 = milligrams NaCl in contaminated swatches after drycleaning, F_R

(2) (milliliters KCNS solution for blank — milliliters KCNS solution for sample) × N × 58.5 × 7 swatches = milligrams NaCl transferred during drycleaning, F_T

(3) $$\frac{\text{milligrams Nacl, } F_R\text{ , } \times 100}{\text{milligrams NaCl, original}} =$$

% residual salt, F_R

(4) $$\frac{\text{milligrams NaCl, } F_T\text{ , } \times 100}{\text{milligrams NaCl, original}} =$$

% transferred salt, F_T

SUGAR DETERMINATION IN CONTAMINATED COTTON FABRIC

The sample of fabric was soaked for 15 minutes in three successive 25 milliliter portions of distilled water. After each extraction, the excess water was squeezed from the fabric and the water transferred to a 100-milliliter volumetric flask. To each 75 milliliters of wash water, 3 milliliters of concentrated hydrochloric acid were added and the solution allowed to stand at room temperature for 24 hours to hydrolyze the sucrose. At the end of the inversion period, the acid was neutralized with powdered sodium carbonate and diluted to exactly 100 milliliters with distilled water. One milliliter aliquots of this solution were then analyzed for reducing sugar by the method of Somogyi (38).

Because of the empirical nature of the analytical method, the results were all calculated as glucose using the Somogyi glucose equivalent of 0.135 milligram of glucose per milliliter of 0.005 N. $Na_2S_2O_3$. The sugar present, calculated as glucose, was then expressed as the percent remaining on the fabric as compared to a sample containing the same quantity of added sugar, but not subject to drycleaning.

In the case of the determination of sugar transferred to uncontaminated swatches from the contaminated swatches during simulated drycleaning tests, only one of the seven swatches was extracted with water. However, 5-milliliter aliquots of the extract were taken for analysis instead of 1-milliliter as in the previous example. The total amount of sugar transferred was then estimated by multiplying this value by seven. The results obtained are summarized in Tables 23 and 24.

Table 23.—Sugar transfer from contaminated to uncontaminated cotton fabric during drycleaning using 0.5% and 4.0% glyceryl monooleate S-1097 in Stoddard solvent containing various amounts of added water.

Additive conc., (%)	Water added ml./1.	Sugar after dry cleaning, %		Sugar in bath, %	Ratio $\frac{F_R}{F_T}$
		F_R , Fabric residual sugar	F_T , Fabric transferred sugar		
—	—	100.0	0.0	0.0	—
0.5	0	64.0	30.7	5.3	2.1
.5	1	109.1	26.3	.0	4.1
.5	3	90.8	17.5	.0	5.1
.5	5	86.0	21.8	.0	3.9
4.0	0	72.0	24.1	3.9	3.0
4.0	1	90.6	28.5	.0	3.2
4.0	3	92.4	21.8	.0	4.2
4.0	5	97.0	21.8	.0	4.4

Table 24.—Sugar transfer from contaminated to uncontaminated cotton fabric during drycleaning when using 0.5% and 4% Street's 886 in Stoddard solvent containing various amounts of added water.

Additive conc., (%)	Water added ml./1	Sugar after dry cleaning, %		Sugar in bath, %	Ratio $\frac{F_R}{F_T}$
		F_R, Fabric residual sugar	F_T, Fabric transferred sugar		
—	—	100.0	0.0	0.0	—
0.5	0	95.4	4.4	.2	21.6
.5	1	89.4	10.9	.0	8.2
.5	3	100.0	4.4	.0	22.7
.5	5	77.3	15.1	7.6	5.1
4.0	0	68.7	15.1	16.2	4.6
4.0	1	86.0	15.1	.0	5.7
4.0	3	63.4	10.9	25.7	5.8
4.0	5	59.4	31.5	9.1	1.9

Calculations: ($Na_2S_2O_3 = 0.005$ N)

(1) (milliliters $Na_2S_2O_3$ for blank—milliliters $Na_2S_2O_3$ for sample) × 0.135 × 100 = milligrams residual glucose in contaminated swatch, F_R

(2) (milliliters $Na_2S_2O_3$ for blank—milliliters $Na_2S_2O_3$ for sample) × 0.135 × 20 × 7 swatches = milligrams glucose transferred to uncontaminated cloth during drycleaning, F_T

(3) $$\frac{\text{milligrams glucose, } F_R\text{, } \times 100}{86.4 \text{ mg. glucose original}} =$$

%, residual sugar, F_R

(4) $$\frac{\text{milligrams glucose, } F_T\text{, } \times 100}{86.4 \text{ mg. glucose original}} =$$

%, transferred sugar, F_T

DISCUSSION

In ordinary drycleaning practice the amount of water added to the drycleaning washer in the form of an emulsion varies from about one-fourth to one-half of an ounce per pound of clothes. It is claimed that this addition of water results in a decrease in the number of spots requiring the use of water to remove, and in the number of items that must be water-washed. This would indicate that the water-soluble materials in the spots are either solubilized or swollen by the added water, so that the mechanical action of the washer removes them from the fabric. There is no doubt that the surface spots are removed to some extent by mechanical agitation. The question of solubilization and transfer of sugar and salt from contaminated to uncontaminated swatches when drycleaned in the same bath has been given consideration in this study.

The data in Tables 20, 21, 22, 23, and 24 indicate that drycleaning with Stoddard solvent removes both salt and sugar from contaminated cotton fabric and redeposits it on other fabric in the bath. The salt data, Tables 20, 21, and 22, indicate that the amount of salt removed and redeposited is increased by additional moisture in the bath. This was not as well demonstrated for sugar. The results with both salt and sugar using Street's 886, and with salt only using glyceryl monooleate, Tables 20, 21, and 24, give some indication that the amount of such soil removed and redeposited is more with 4.0% additive than with 0.5% additive. Other results reported in Tables 22 and 23 do not bear this out.

The results with salt, Tables 20, and 21, indicate that both increasing additive concentration and increasing water content of bath increase the amount of salt held in the bath itself. In general the results with sugar are inconclusive although there is a trend in this direction with selected detergents, Table 24. Whether a high concentration of salt in the bath is desirable or undesirable in such systems remains unanswered. The high concentration implies that it has been removed from the contaminated fabric, but does not insure that it will not be deposited on the next load.

The data in Tables 20, 21, and 22, indicate that at equivalent concentrations Street's 886 and glyceryl monooleate remove more salt than does Aerosol-OT.

During tests made in a commercial drycleaning plant on the redeposition of soil on cotton fabric, large swatches of white cotton fabric were run 10 times with the regular drycleaning loads. Upon analyzing portions of these swatches, salt was found to be present. The effect of the presence of salt in solubilized water in drycleaning solvents on the detergent efficiency of the additive-solvent-water-soil-fabric system was not included in this investigation.

Although the transfer of sugar and salt from soiled to unsoiled cotton fabric was not studied on visibly soiled fabric, it is evident that transfer of water-soluble soils would and does occur during drycleaning. In order to minimize this, it is necessary to select a drycleaning additive that has high detergent efficiency in low concentration in the absence of added water and does not in itself cause transfer of water-soluble soils. It is desirable that the additive cause the water-soluble soil to remain in suspension in the solvent so that it can be removed by filtration. Solvent distillation can, of course, be used as a last resort. Other techniques used to clean the solvent consist of throwing into the dirty solvent, cotton sacks wet with water and then following this with dry sacks (18). The economics of this operation is questionable.

The recognition of invisible, transferable soils as a factor in drycleaning is important. The problem is not limited to cotton goods (22) since the same factors are operating regardless of the type of fiber used in garment manufacture.

CONCLUSIONS

(1) Sugar and salt, as representative of water soluble soils, have been found to transfer from contaminated to uncontaminated cotton fabric during a typical drycleaning operation with Stoddard solvent.

(2) The concentration and type of drycleaning additive and the amount of water present in the system were found to affect the extent of transfer of salt from one fabric to another.

(3) The use of drycleaning additives having high detergency efficiency at low concentrations with small amounts of added water should result in a minimum transfer of water-soluble soils from dirty to clean fabric in mixed loads.

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